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# A STUDY OF THE EFFECTS OF CYCLIC FREEZING ON A CLAYEY GRAVEL STABILIZED WITH ADDITIVES AND THE INFLUENCE OF THESE ADDITIVES ON PERMEABILITY

A DISSERTATION

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR

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DEPARTMENT OF CIVIL ENGINEERING

BY

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Edmonton, Alberta
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## ABSTRACT

### Part A

The effect of cyclic freezing and thawing on a poor quality sub base material modified with additives was investigated. The minus number 40 sieve fraction of a plastic clayey gravel was treated with various small quantities of Portland cement and lime fly ash admixture. A series of Atterberg Limit tests were run on a set of treated samples cured at constant temperature, and an identically treated set subjected to cyclic freezing and thawing. It was found:

(a) The additives brought about a marked modification and improvement in the adverse plasticity characteristics of the native material.

(b) Cyclic freezing and thawing had a further beneficial influence.

### Part B

A laboratory testing apparatus for measuring the permeability of a minus three inch clayey-gravel mixture was developed. Permeability measurements were made on two such materials at various densities, both in their native state and treated with the above mentioned additives. It was found:

(a) The permeability of clayey-gravel mixtures of the gradations tested vary over an extremely wide range and are sensitive to seven different variables.

(b) The additives cause a slight increase in permeability.

(c) The permeability test is not suitable for routine classification of this type of material.

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# CHAPTER I

## INTRODUCTION

In many parts of Canada, but particularly in the Prairie Provinces the problem of obtaining good quality granular materials and aggregates suitable for highway and airport pavement construction is becoming increasingly acute. The situation is deteriorating yearly as ever increasing quantities of granular material are required, more rigid quality control is demanded in the construction of modern heavy duty pavements, and known sources of suitable material are being rapidly depleted.

During the last continental glaciation the Prairie region was covered with a heavy mantle of glacial drift or till. It is generally possible to find a deposit of granular material in this mantle but the problem is one of quality. Most of the good quality clean aggregates are currently being obtained from isolated post glacial outwash or fluvial deposits. While these deposits may require some processing such as screening, blending and crushing, they will generally produce a satisfactory material. However these deposits are being rapidly depleted and there are many areas where they do not exist within economic hauling distance of a project. It is in these areas that the Engineer must turn to the parent glacial till as a source of base course and sub base material.

Typically, due to their glacial origin, these deposits are extremely variable and the material is generally poorly graded containing an excessive

quantity of silt or plastic clayey fines and in some cases organic material. Experience has shown that such material cannot be relied upon to perform satisfactorily as a pavement sub base particularly where drainage conditions are poor or where the material is liable to become saturated, as is frequently the case.

The Department of Highways, Province of Alberta, are faced squarely with this problem and have therefore initiated a study of ways and means of treating or stabilizing these typical sub marginal materials in order that they may be safely incorporated in highway sub base and base courses. The study is being carried out by the Research Council of Alberta in co-operation with the Department of Civil Engineering, University of Alberta. This investigation forms part of this continuing study.

Two materials, both plastic clayey soil-aggregate mixtures, that were considered to be typically representative of the problem were selected for this study. The gradation of these typical materials are shown in Plate I. The materials will be classified and described in more detail later but the grain size distribution is introduced here because it is one of the main characteristics that renders them unsuitable for highway construction.

The inter-relationship between gradation, density and stability has been shown by Yoder (15)* in his discussion of granular bases and sub bases.

---

* The numbers in parenthisis refer to the bibliography at the end of Chapter XVI.

He shows that;

(a) the grain size distribution of a well graded soil-aggregate mixture may be represented by the equation;

$$P = 100\left(\frac{d}{D}\right)^n \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where P = percent by weight finer than any sieve size d

D = maximum size of aggregate in the mix

(b) maximum density usually occurs when the exponential n equals 0.5

(c) maximum stability usually occurs when the percentage of fines* in the mix is just slightly less than that required for maximum density.

When the mix contains fine material in excess of the quantity required for maximum density the grain to grain contact between the larger aggregate particles is destroyed and the particles tend to float in a matrix of fines. This loss of granular interlock lowers the friction angle and stability of the mix. By referring to Plate I where the curve of equation (1) has been plotted for a value of n equal to 0.5 it will be seen that the above described condition is one of the characteristics of these materials.

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* In this discussion the term "fines" refers to that material passing the number 200 sieve. The term "binder" refers to that material passing the number 40 sieve including the fines.

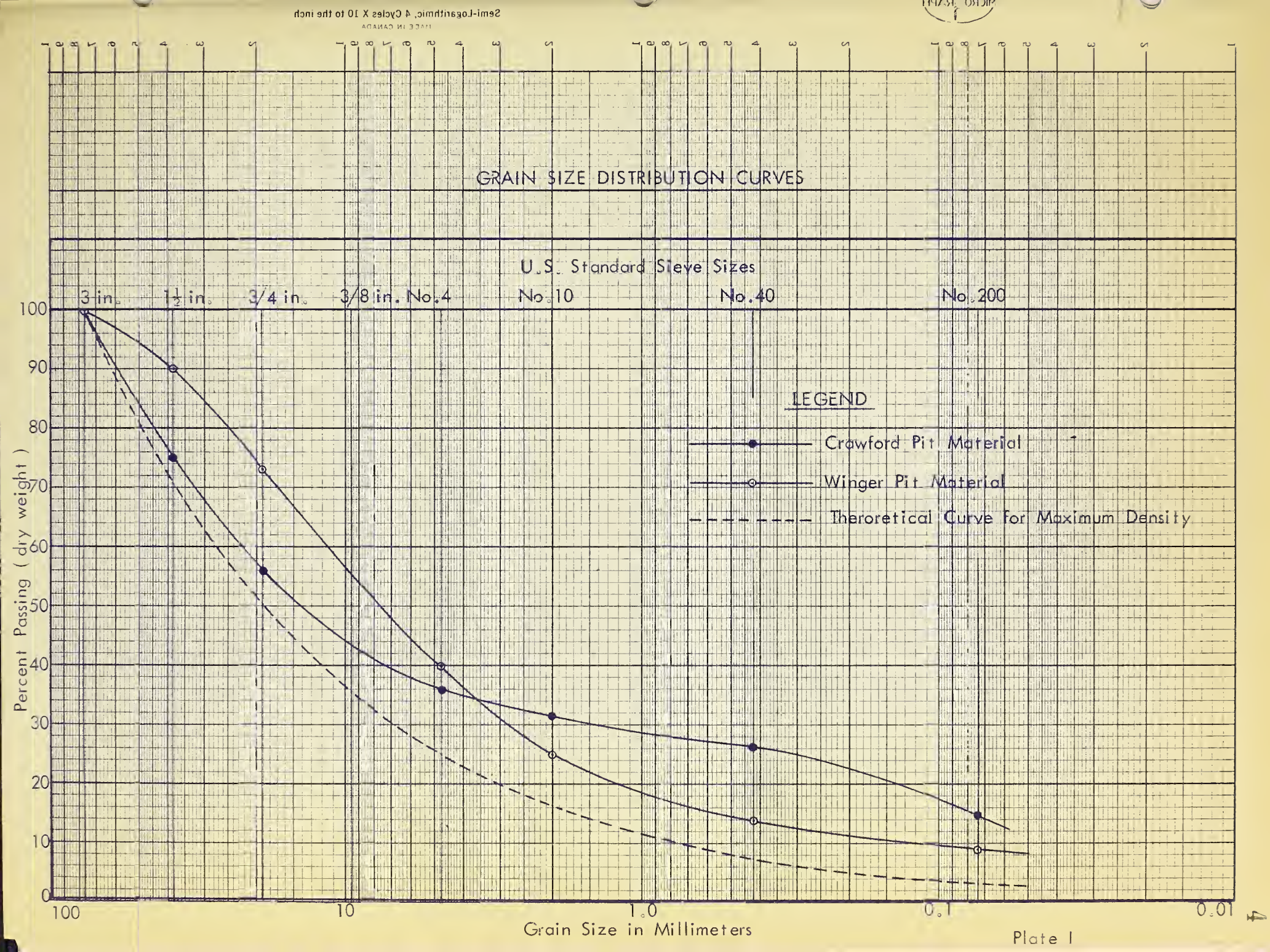

GRAIN SIZE DISTRIBUTION CURVES
U.S. Standard Sieve Sizes
3 in.
1½ in.
¾ in.
⅜ in.
No. 4
No. 10
No. 40
No. 200
LEGEND
Crawford Pit Material
Winger Pit Material
Theroretical Curve for Maximum Density
Percent Passing ( dry weight )
100
90
80
70
60
50
40
30
20
10
0
100
10
1.0
0.1
0.01
Grain Size in Millimeters

Plate I

It follows that if the fines interfere with the grain to grain contact between the larger aggregate particles the stability of the mix will become highly dependant on the strength characteristics of the material causing the interference. One would therefore expect the stability of a soil aggregate mix containing an excess of plastic clayey fines to be highly dependant on moisture content which is a fundamental characteristic of plastic clays. Actually this has been shown by Deklotz (12). He found that for a given percentage of soil binder the higher the plasticity of the binder the lower the stability of the mix. The effect became very pronounced as the binder content was increased beyond that required for maximum density as given by equation (1). Work done by Clark (1) and Millions (2) at the University of Alberta confirms that the material under investigation exhibits this same characteristic; i.e. a marked loss of shearing strength as the moisture content increases above the optimum required for compaction.

That the stability of a soil-aggregate mix containing a highly plastic binder will be adversely affected by moisture has long been recognized by highway engineers and accounts for the frequently used specification which reads in part, "the fraction passing the number 40 sieve shall have a liquid limit not greater than twenty five and a plasticity index not greater than six." (AASHO Designation M147-49) (22). As will be shown later the materials under study will not meet this specification. In summary then,

these materials are unsuitable for use in highway sub bases for two reasons:

(a) They contain an excess quantity of fines.

(b) The binder fraction is too highly plastic.

Previous investigators (1, 2) have shown that the incorporation of small quantities of Portland cement and mixtures of lime and fly ash into these materials brought about definite improvements in their shearing strengths and plasticity characteristics. Their results indicated that the treated material was superior to the native gravel in sustaining load, resisting deflection and distributing load to the sub grade. One question that remained unanswered, however, was the durability of the treated material or the permanency of these effects under the influence of field weathering conditions.

Since the additive concentrations used by these investigators were small, and since the curing times were generally short it was reasonable to assume that most of the gain in shearing strength was due to a modification of the plasticity characteristics of the fines rather than any definite pozlanic or cementing action. It was therefore concluded that the plasticity characteristics could be effectively used to study the influence of cyclic freezing and thawing on the treated materials. This led to part "A" of this investigation, namely the influence of cyclic freezing and thawing on the plasticity characteristics of the binder fraction of a clayey soil-aggregate mixture treated with Portland cement and lime fly ash additives.

Part "B" of this investigation followed from Millions' (2) observations which led him to conclude that the marked loss of strength with increasing moisture content was due to the low permeability of the material. He reasoned that the effect of the additives was to increase the permeability of the material thereby permitting more rapid dissipation of pore pressure and this, in accordance with Casegrande's Working Hypothesis (14) would explain the higher shearing strengths. It was then reasoned that the coefficient of permeability might possibly be suitable criteria to use in the selection, classification and treatment of these sub marginal materials. It was also reasoned that if the coefficient of permeability should prove to be a useable criteria the permeability test would be much more adaptable to routine and field laboratory use and would require a much smaller investment in testing equipment than would the twelve inch vacuum triaxial test. Part "B" of this investigation, namely a study of the permeability of the native materials and the influence of the additives thereon was therefore undertaken.

# PART A

## A STUDY OF THE INFLUENCE OF CYCLIC FREEZING AND THAWING ON A CLAYEY GRAVEL STABILIZED WITH ADDITIVES.

# CHAPTER II
# CLASSIFICATION AND ANALYSIS OF THE MATERIAL INVESTIGATED

The material used in this part of the investigation was obtained from the Crawford pit (SW 33-36-20-W4) near Stettler, Alberta. It was a very dirty, dark grey clayey gravel mixture containing an excessive quantity of plastic clayey fines and some organic matter. The gravel fraction ranged from sub angular to rounded. The material was a GF soil in accordance with the U.S. Corps of Engineers Airfield Classification System (3). The AASHO classification was A-2-6 with a group index of zero. (4).

Table I shows the average results of twelve sieve analysis and Atterberg Limit tests on the Crawford pit material carried out by the Department of Highways and reported by Clark (1). Since this analysis was done by experienced and competent personnel and the results are considered reliable it was not deemed necessary to duplicate the work for the purpose of this investigation. This gradation was therefore taken as average for the pit.

The laboratory prepared gradation of the Crawford pit material used by Millions (2) in his triaxial tests and the Atterberg Limits of the untreated minus number 40 sieve fraction thereof are shown in Table II.

TABLE I

Mechanical Analysis and Atterberg Limits

Crawford Pit

Reported by Clark

| Sieve Size | % Passing (Dry Wt.) |
|---|---|
| 3" | 100 |
| 1½" | 90 |
| 3/4" | 73 |
| No.4 | 40 |
| No.10 | 25 |
| No.40 | 14 |
| No.200 | 8.9 |
| Oversize 6% | |

| Atterberg Limits of minus No.40 fraction | |
|---|---|
| Liquid Limit | 35.8 |
| Plastic Limit | 19.5 |
| Plasticity Index | 16.3 |

TABLE II

Mechanical Analysis and Atterberg Limits

Crawford Pit

Reported by Millions

| Sieve Size | % Passing (Dry Wt.) |
|---|---|
| 3" | 100 |
| 1½" | 93 |
| 3/4" | 75 |
| No.4 | 43 |
| No.10 | 29 |
| No.40 | 17 |
| No.200 | 11.2 |

| Atterberg Limits of minus No.40 fraction | |
|---|---|
| Liquid Limit | 38.5 |
| Plastic Limit | 20.3 |
| Plasticity Index | 18.2 |

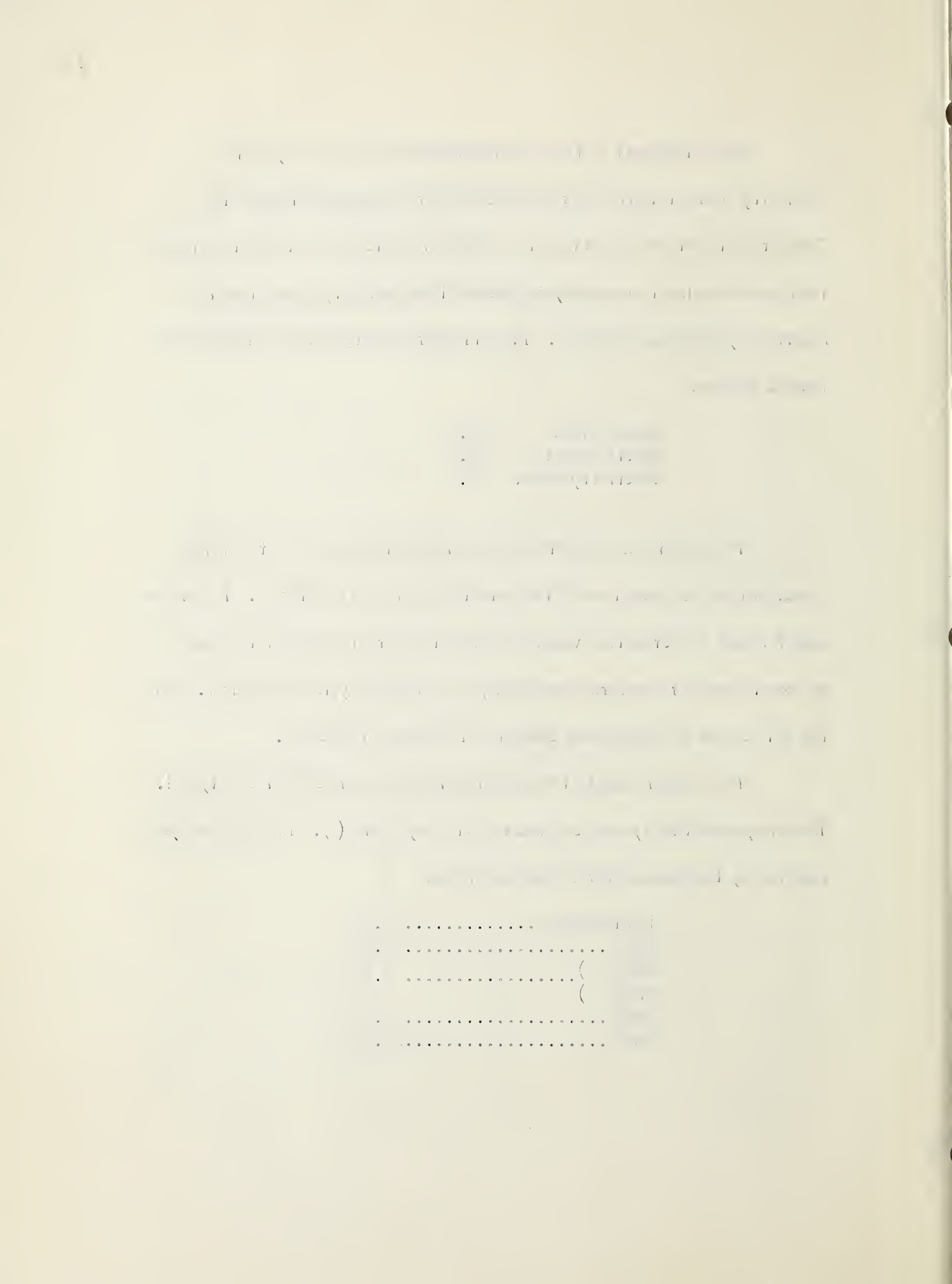
Since this part of the investigation involved a study of the plasticity characteristics of the minus number 40 sieve fraction of the Crawford pit material an attempt was made to obtain from the pit material that would duplicate as nearly as possible the plasticity characteristics reported by Clark and Millions. The Atterberg Limits of the material used were as follows:

| | |
|---|---|
| Liquid Limit | 40.4 |
| Plastic Limit | 23.7 |
| Plasticity Index | 16.7 |

The variations in limit values of the material used in the three investigations is indicative of the variation in the pit material. The gravel used for each investigation was taken from the pit at different times and an exact duplicate material could only be obtained by trial and error. Since the pit is over 100 miles from Edmonton this was not feasible.

The cement used in this investigation was normal Portland Type I. The analysis of the fly ash used was reported by Clark (1). The lime analysis, supplied by the manufacturer, was as follows:

| | |
|---|---|
| Ignition Loss | 22.9% |
| $SiO_2$ | 0.3% |
| $FeO_2$ ) $AlO_2$ ) | 0.4% |
| MgO | 1.2% |
| CaO | 74.8% |



# CHAPTER III

## PROCEDURE

The material was received from the pit in 100 lb. bags. Upon receipt it was spread out in shallow pans and allowed to come to "air dry" moisture equilibrium. This process was assisted by periodic stirring and directing jets of air over the samples as they dried.

The air dried material was then put through the Los Angeles Abrasion machine in 50 lb. batches; each batch receiving 100 revolutions in the machine with the steel balls removed. The purpose of this treatment was to break up the clay lumps and remove the clay adhering to the larger aggregate particles. The pulverized material was then broken down into sized fractions by hand sieving over the following sieves: 3, $1\frac{1}{2}$, 3/4 and 3/8 inches. The minus 3/8 inch material was then put through a ROTEX power driven sieving machine and the following fractions were obtained: minus numbers 4, 10, and 40.

To obtain uniformity the whole minus number 40 fraction was placed in a tilting drum type concrete mixer and mixed in the dry state for three minutes. It was then discharged into a large plaster boat and spread out in a uniform layer. Approximately 35 lbs. of material was then taken from the plaster boat for use in this part of the investigation. The remaining material was put in bags and stored for part "B" of the investigation.

The minus number 40 fraction for use in the freeze thaw tests was placed in a large mixing bowl and thoroughly mixed by hand to insure absolute uniformity. The material was then weighed out in 1200 gram (air dry weight) batches and placed in 2 lb. honey cans.

The following additive concentrations expressed as a percentage of the dry weight of the untreated material were used. *

(a) Portland Cement 2, 5 and 8 percent

(b) Lime-fly ash (in the ratio 1:2) 3, 6 and 10.5 percent

These concentrations were selected to cover the range used by Clark (1) and Millions (2). The additives were then weighed out and added to the dry material. After each addition each sample was thoroughly mixed by hand in the dry state to ensure uniform dispersion of the additives. The containers were then capped and the samples were placed in the storage room in the dry state to await the testing programme.

Since other investigators (1,2,9) found that definite changes in the Atterberg Limit values of the treated material occur as a function of curing time when cured at constant temperature, it was necessary to prepare two separate samples for each additive concentration being studied. One sample, the time control sample, was cured at constant temperature while the other

---

* Unless otherwise stated all additive concentrations in this investigation have been computed on a dry weight basis and are expressed as a percentage of the dry weight of the untreated material.

was subjected to cyclic freezing and thawing. In this way the effect of the cyclic freezing could be co-related to the changes that normally occur as a function of curing time.

Some preliminary Atterberg Limit tests on the material revealed the difficulty that was to be encountered in obtaining reliable and reproduceable results at the higher additive concentrations. It was apparent that a departure from A.S.T.M. Standard Procedure (5) would have to be made in forming the groove in the liquid limit device. When the groove was formed in accordance with A.S.T.M. Procedure the two halves of the divided specimen would come together simply by sliding on the surface of the cup. This meant that the resistance to sliding on a brass surface was being measured rather than the shearing strength of the material.

Several dozen tests were run in order to evolve a grooving procedure that would eliminate this problem and produce consistent results. The procedure evolved was as follows:

The ASTM Standard grooving tool was used (5). The cup was placed in the limit device and the height of fall adjusted to 1.0 cm. Sufficient material was placed in the cup to form a flat level surface level with the outer lip of the cup in the lowered position. The tool with its handle held at an angle of 45 from the vertical was placed squarely at the geometric center of the soil surface. It was then pressed firmly downward until it contacted the bottom of the cup. Holding it firmly against the cup the tool was then pulled

toward the operator in a circular motion so that the handle was vertical as the tool slid off the lip of the cup.

This resulted in a uniform groove from the impact point to the lip of the cup and left a small bridge of soil on the hinge side of the impact point. This soil bridge effectively eliminated the sliding action previously mentioned. Approximately two dozen trial runs showed that different operators using this procedure could achieve consistent results and the procedure was adopted as standard for this investigation.

Preliminary tests were run to determine time and temperature requirements for one complete freeze thaw cycle of the 1200 gram samples. Trials indicated that 6 hours at an ambient air temperature of -30 C were ample to ensure complete freezing of the specimen and that it would thaw at an ambient air temperature of +20 C in the same time. With this information a testing schedule was set up and rigidly followed to ensure that all specimens received exactly the same treatment. The schedule is shown in Appendix A. It will be noted that the samples were removed from the frost room twelve hours prior to testing. This was done to ensure the samples being at room temperature when the tests were made.

The freeze thaw programme commenced on June 24th (day No. 1) on the schedule. At 1000 hours sufficient distilled water was added to the samples indicated on the schedule to bring them close to but below their liquid limit. The samples then cured at moist room temperature (22 $\pm$ 2 C) for six hours

prior to placing the freeze thaw samples in the frost room.

The testing schedule best illustrates the treatment the samples received. The limit tests were run in pairs, as far as possible by the same operator using the same equipment. Frequent cross checks between two operators at different times during the programme served as a check on uniformity of procedure and consistency of results.

Moisture control during the programme was not rigid but each day all samples were thoroughly mixed and brought to approximately the same consistency; just below the liquid limit. This presented some difficulty in the early stages when rapid changes were occuring and the samples with the higher additive contents built up a definite granular structure that required considerable manipulation to break down before tests could be run.

Throughout this programme ASTM procedures were used as far as possible. Only two major departures were made. One, previously described, concerned the method of grooving, the other was the method of preparing the minus number 40 fraction where the Los Angeles Abrasion machine was utilized to break up the clay lumps. Obviously a mortar and pestle would not be suitable for this type of material in the quantities required.

## CHAPTER IV

## FREEZE THAW TEST RESULTS

The Atterberg Limit test results obtained in part "A" of this investigation are presented here in three forms in the order of chronological development:

Form "A" - Table III

Form A is a table of numerical values wherein the freeze thaw and corresponding time control test results for each additive concentration are arranged in pairs in order of curing time.

Form "B" - Plates II to VII inclusive

Form B is a graphical presentation of the data. For each additive concentration a graph has been prepared showing the observed Atterberg Limits as a function of the number of freeze thaw cycles and corresponding constant temperature curing time.

Form "C" - Plates VIII to XI inclusive

In this form the data are presented in a series of composite plots of Atterberg Limits versus percentage additive which show the influence of the three major variables; additive content, time and temperature.

# TABLE 3

SUMMARY OF ATTERBERG LIMIT TEST RESULTS ON CRAWFORD PIT FINES

| ADDITIVE CONTENT % DRY WT. | NO. OF FREEZE THAW CYCLES | | 1 | 3 | 12 | 25 | 48 |
|---|---|---|---|---|---|---|---|
| 1% LIME | SAMPLE 1 FREEZE THAW | $W_L$ | 38.2 | 39.1 | 38.3 | 38.2 | 38.2 |
| | | $W_P$ | 31.9 | 31.7 | 29.3 | 28.2 | 27.0 |
| | | $I_P$ | 6.3 | 7.4 | 9.0 | 10.0 | 11.2 |
| 2% FLY ASH | SAMPLE 7 TIME CONTROL | $W_L$ | 40.4 | 41.1 | 40.8 | 40.9 | 42.1 |
| | | $W_P$ | 32.5 | 32.8 | 32.4 | 31.1 | 28.6 |
| | | $I_P$ | 7.9 | 8.3 | 8.4 | 9.8 | 13.5 |
| 2% LIME | SAMPLE 2 FREEZE THAW | $W_L$ | 36.2 | 38.6 | 35.9 | 36.7 | 34.4 |
| | | $W_P$ | 32.5 | 31.3 | 31.0 | 28.8 | 27.9 |
| | | $I_P$ | 3.7 | 7.3 | 4.9 | 7.9 | 6.5 |
| 4% FLY ASH | SAMPLE 8 TIME CONTROL | $W_L$ | 40.1 | 41.0 | 42.4 | 44.0 | 44.1 |
| | | $W_P$ | 32.7 | 33.6 | 34.3 | 33.9 | 34.7 |
| | | $I_P$ | 7.4 | 7.4 | 8.1 | 10.1 | 9.4 |
| 3.5% LIME | SAMPLE 3 FREEZE THAW | $W_L$ | 33.6 | 33.5 | 34.0 | 34.5 | 34.3 |
| | | $W_P$ | N. P. | 31.9 | 32.6 | 31.3 | 31.4 |
| | | $I_P$ | 0 | 1.6 | 1.4 | 3.2 | 2.9 |
| 7% FLY ASH | SAMPLE 9 TIME CONTROL | $W_L$ | 37.8 | 40.1 | 41.4 | 43.6 | 47.1 |
| | | $W_P$ | N. P. | 37.8 | 36.8 | 36.8 | 39.1 |
| | | $I_P$ | 0 | 2.3 | 4.6 | 6.8 | 8.0 |
| 2% N. P. C. | SAMPLE 4 FREEZE THAW | $W_L$ | 39.3 | 38.2 | 37.6 | 35.3 | 35.5 |
| | | $W_P$ | 32.6 | 31.8 | 29.8 | 28.9 | 29.5 |
| | | $I_P$ | 6.7 | 6.4 | 7.8 | 6.4 | 6.0 |
| | SAMPLE 10 TIME CONTROL | $W_L$ | 42.2 | 42.9 | 43.5 | 44.2 | 47.3 |
| | | $W_P$ | 33.1 | 33.3 | 33.0 | 33.9 | 33.0 |
| | | $I_P$ | 9.1 | 9.6 | 10.5 | 10.3 | 14.3 |
| 5% N. P. C. | SAMPLE 5 FREEZE THAW | $W_L$ | 39.8 | 39.9 | 38.7 | 38.2 | 37.7 |
| | | $W_P$ | 33.9 | 35.5 | 33.3 | 34.1 | 33.2 |
| | | $I_P$ | 6.3 | 4.4 | 5.4 | 4.1 | 4.5 |
| | SAMPLE 11 TIME CONTROL | $W_L$ | 44.3 | 45.5 | 47.2 | 48.3 | 51.3 |
| | | $W_P$ | 35.1 | 38.3 | 39.1 | 42.8 | 43.3 |
| | | $I_P$ | 9.2 | 7.2 | 7.4 | 5.5 | 8.0 |
| 8% N. P. C. | SAMPLE 6 FREEZE THAW | $W_L$ | 40.6 | 38.3 | 38.2 | 36.2 | 37.6 |
| | | $W_P$ | 35.8 | 36.2 | 35.2 | 33.8 | 34.7 |
| | | $I_P$ | 4.8 | 2.1 | 3.0 | 2.4 | 2.9 |
| | SAMPLE 12 TIME CONTROL | $W_L$ | 43.9 | 46.3 | 47.3 | 48.4 | 50.5 |
| | | $W_P$ | 39.1 | 41.8 | 42.5 | 42.5 | 44.8 |
| | | $I_P$ | 4.8 | 4.5 | 4.8 | 5.9 | 5.7 |

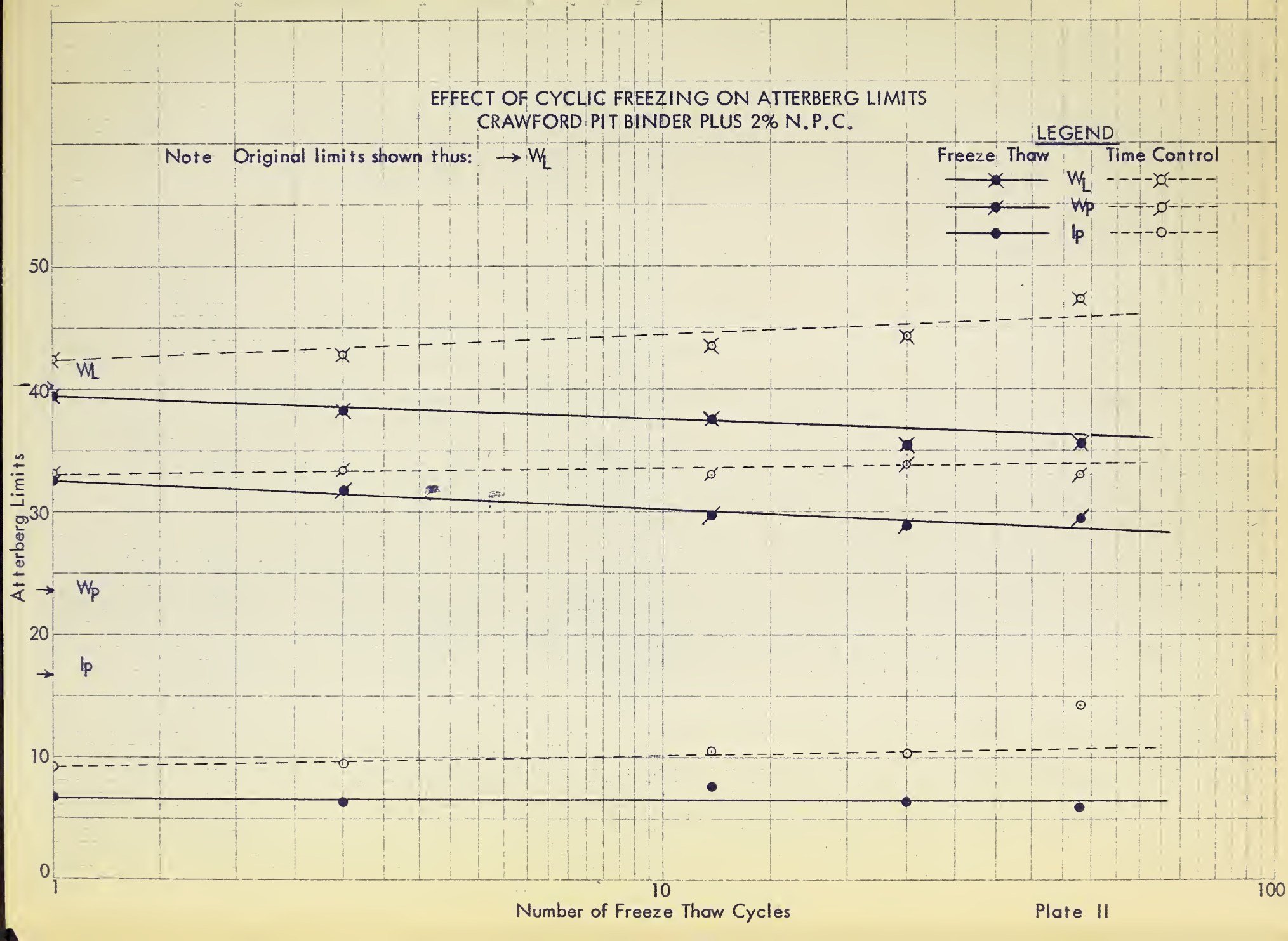

EFFECT OF CYCLIC FREEZING ON ATTERBERG LIMITS
CRAWFORD PIT BINDER PLUS 2% N.P.C.
Note Original limits shown thus: → $W_L$
LEGEND
Freeze Thaw
Time Control
$W_L$
$W_P$
$I_P$
Atterberg Limits
50
40
30
20
10
0
1
10
100
Number of Freeze Thaw Cycles

Plate II

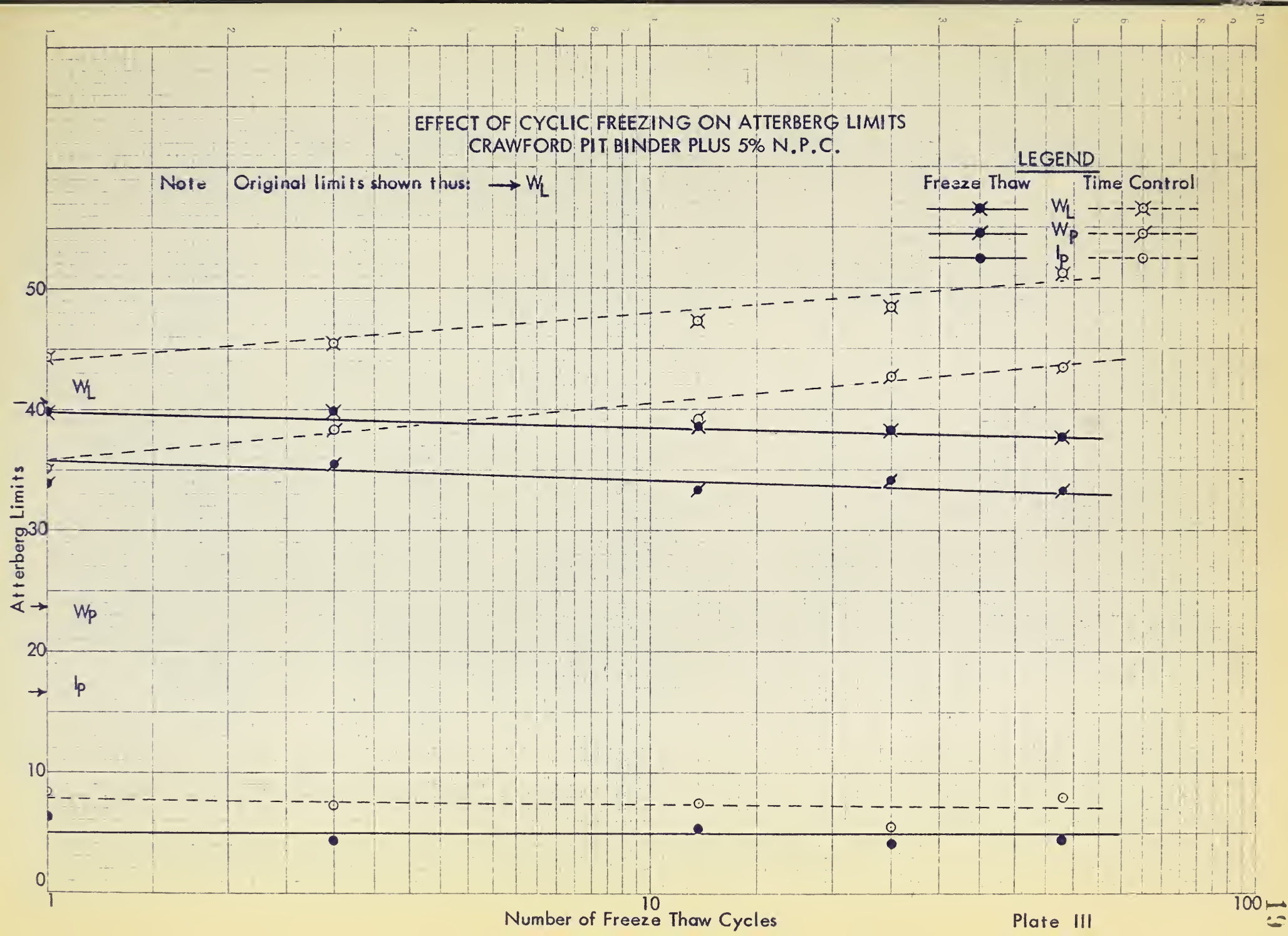

EFFECT OF CYCLIC FREEZING ON ATTERBERG LIMITS
CRAWFORD PIT BINDER PLUS 5% N.P.C.
Note Original limits shown thus: → $W_L$
LEGEND
Freeze Thaw
Time Control
$W_L$
$W_P$
$I_P$
Atterberg Limits
50
40
30
20
10
0
$W_L$
$W_P$
$I_P$
1
10
100
Number of Freeze Thaw Cycles

Plate III

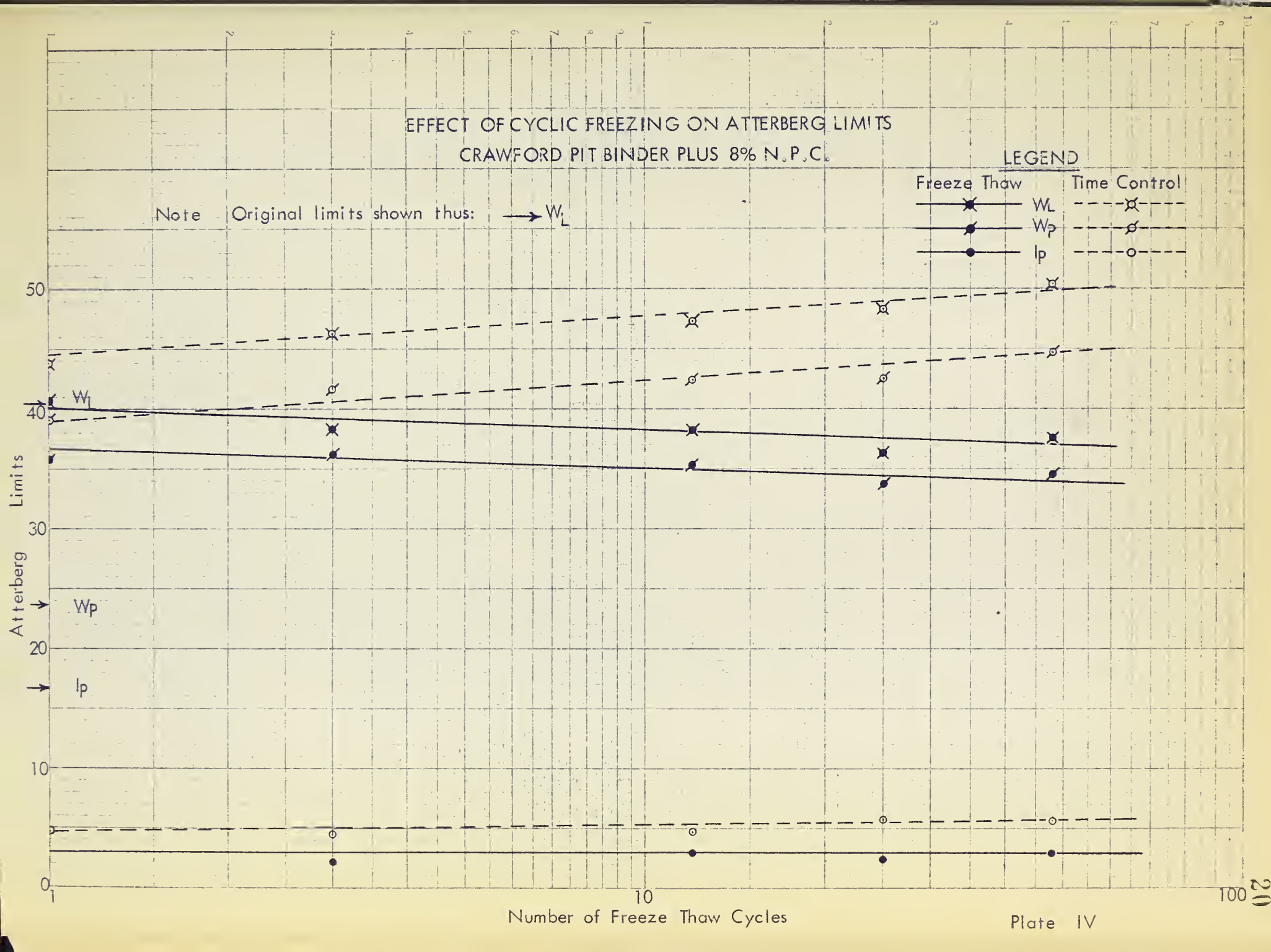
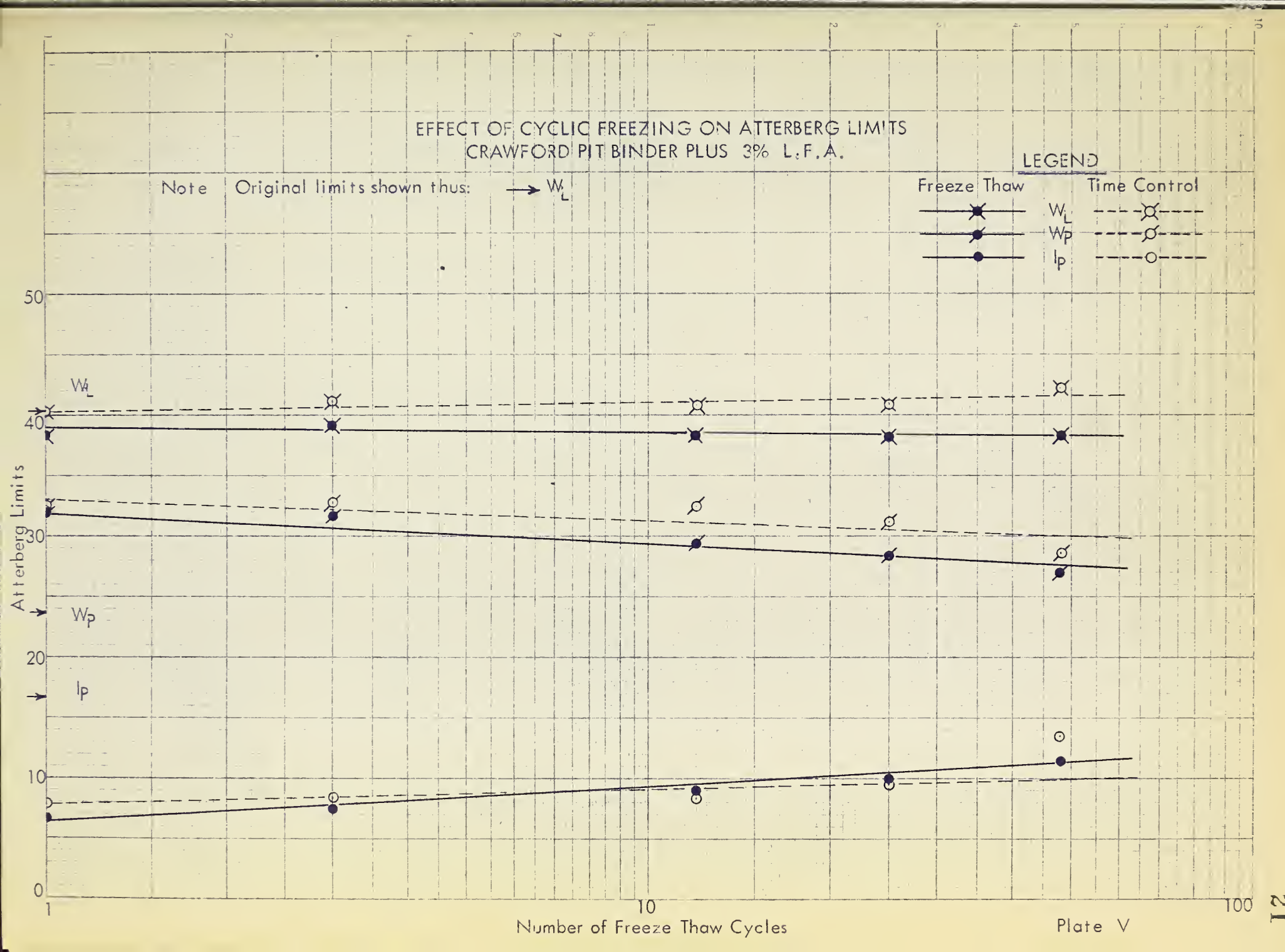
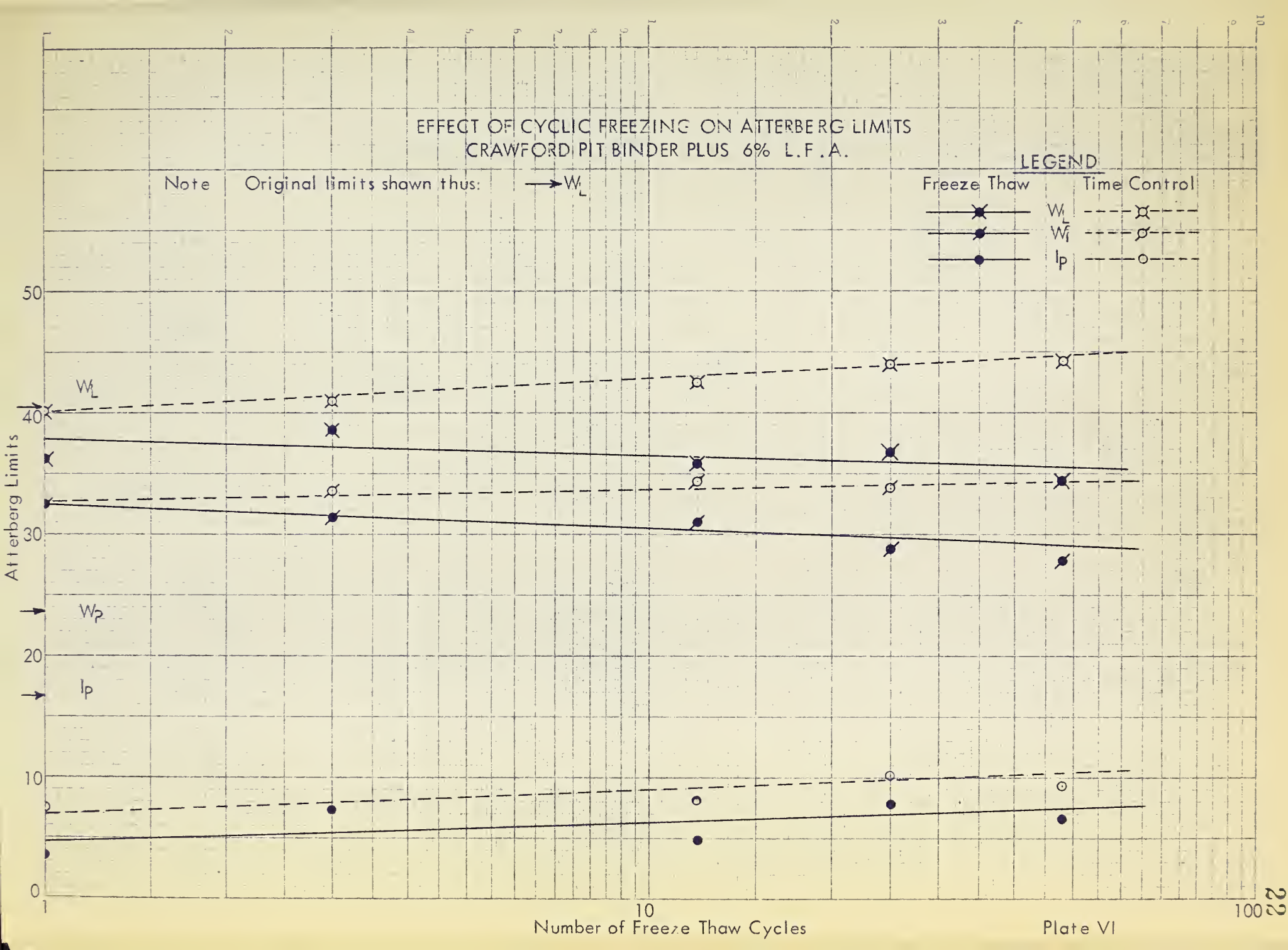
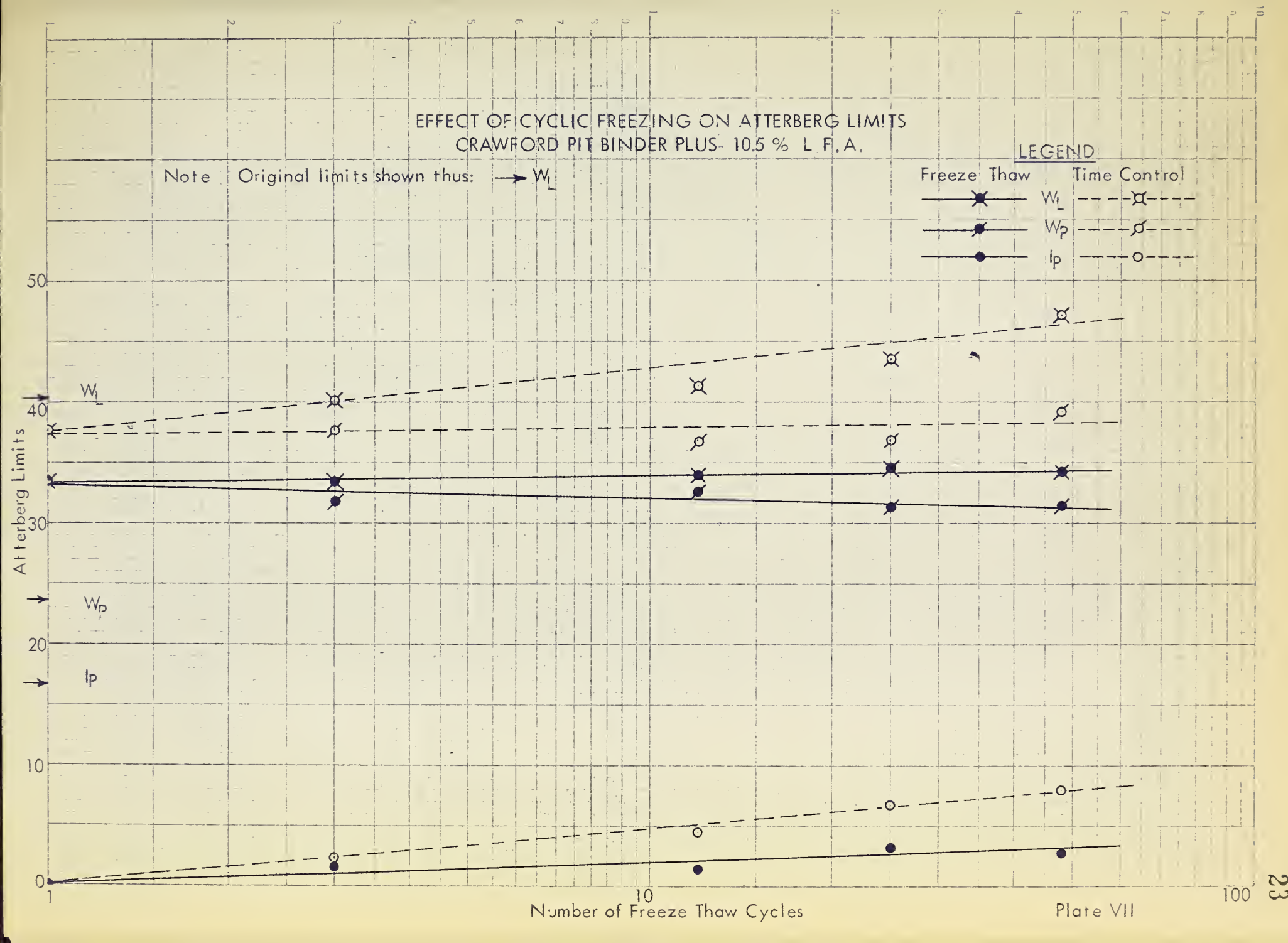

EFFECT OF CYCLIC FREEZING ON ATTERBERG LIMITS
CRAWFORD PIT BINDER PLUS 8% N.P.C.
LEGEND
Freeze Thaw
Time Control
$W_L$
$W_P$
$I_P$
Note Original limits shown thus: → $W_L$
Atterberg Limits
50
40
30
20
10
0
1
10
100
Number of Freeze Thaw Cycles

Plate IV


EFFECT OF CYCLIC FREEZING ON ATTERBERG LIMITS
CRAWFORD PIT BINDER PLUS 3% L.F.A.
Note Original limits shown thus: → $W_L$
LEGEND
Freeze Thaw
Time Control
$W_L$
$W_P$
$I_P$
Atterberg Limits
50
40
30
20
10
0
1
10
100
Number of Freeze Thaw Cycles
Plate V


EFFECT OF CYCLIC FREEZING ON ATTERBERG LIMITS
CRAWFORD PIT BINDER PLUS 6% L.F.A.
Note Original limits shown thus: → $W_L$
LEGEND
Freeze Thaw
Time Control
$W_L$
$W_P$
$I_P$
Atterberg Limits
Number of Freeze Thaw Cycles
Plate VI
22


EFFECT OF CYCLIC FREEZING ON ATTERBERG LIMITS
CRAWFORD PIT BINDER PLUS 10.5 % L F.A.
Note Original limits shown thus: → $W_L$
LEGEND
Freeze Thaw
Time Control
$W_L$
$W_P$
$I_P$
Atterberg Limits
50
40
30
20
10
0
1
10
100
Number of Freeze Thaw Cycles
Plate VII

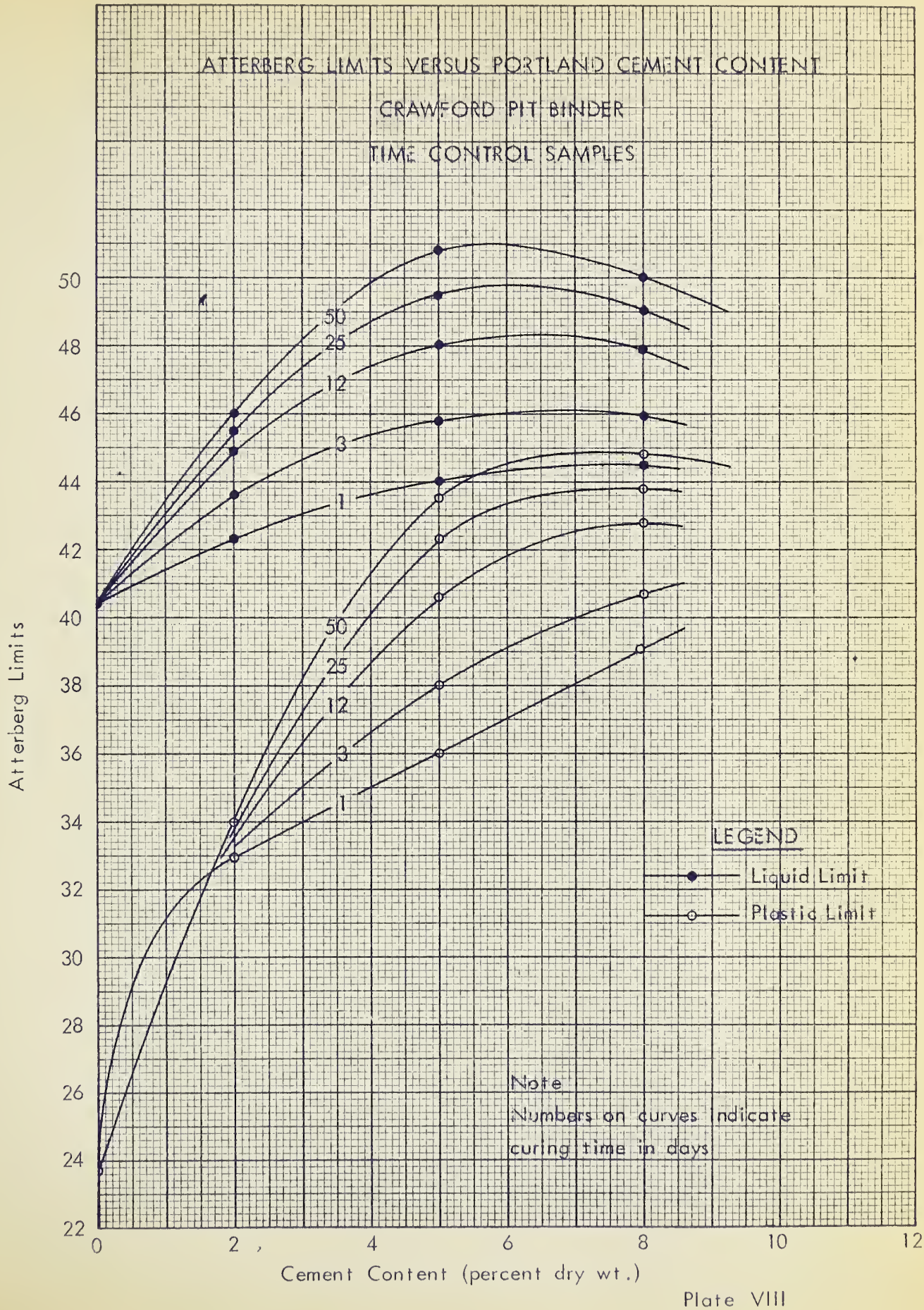

ATTERBERG LIMITS VERSUS PORTLAND CEMENT CONTENT
CRAWFORD PIT BINDER
TIME CONTROL SAMPLES
Atterberg Limits
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
0
2
4
6
8
10
12
Cement Content (percent dry wt.)
50
25
12
3
1
50
25
12
3
1
LEGEND
Liquid Limit
Plastic Limit
Note
Numbers on curves indicate
curing time in days

Plate VIII

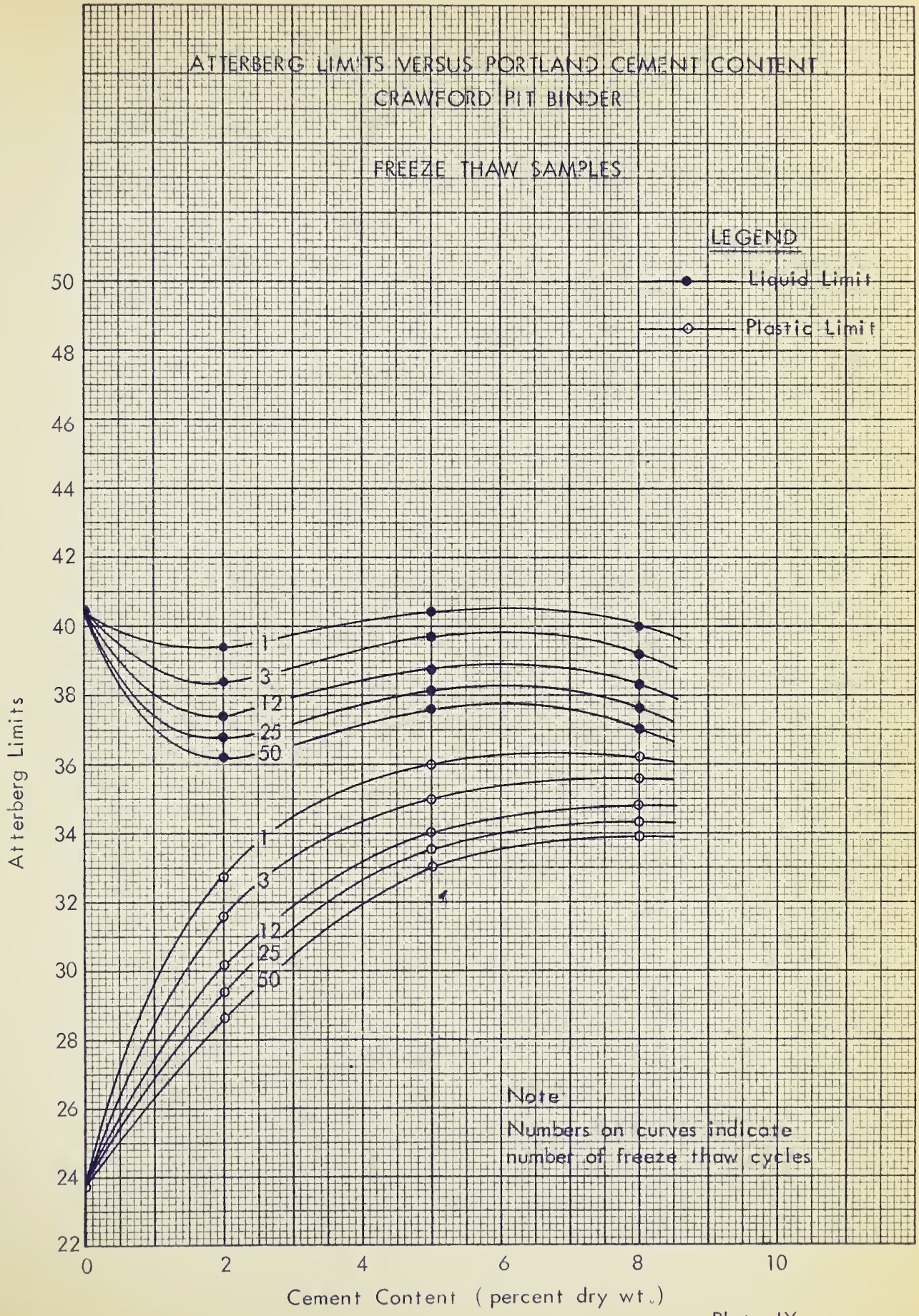

ATTERBERG LIMITS VERSUS PORTLAND CEMENT CONTENT
CRAWFORD PIT BINDER
FREEZE THAW SAMPLES
LEGEND
Liquid Limit
Plastic Limit
Atterberg Limits
Cement Content ( percent dry wt.)
1
3
12
25
50
Note
Numbers on curves indicate
number of freeze thaw cycles

Plate IX

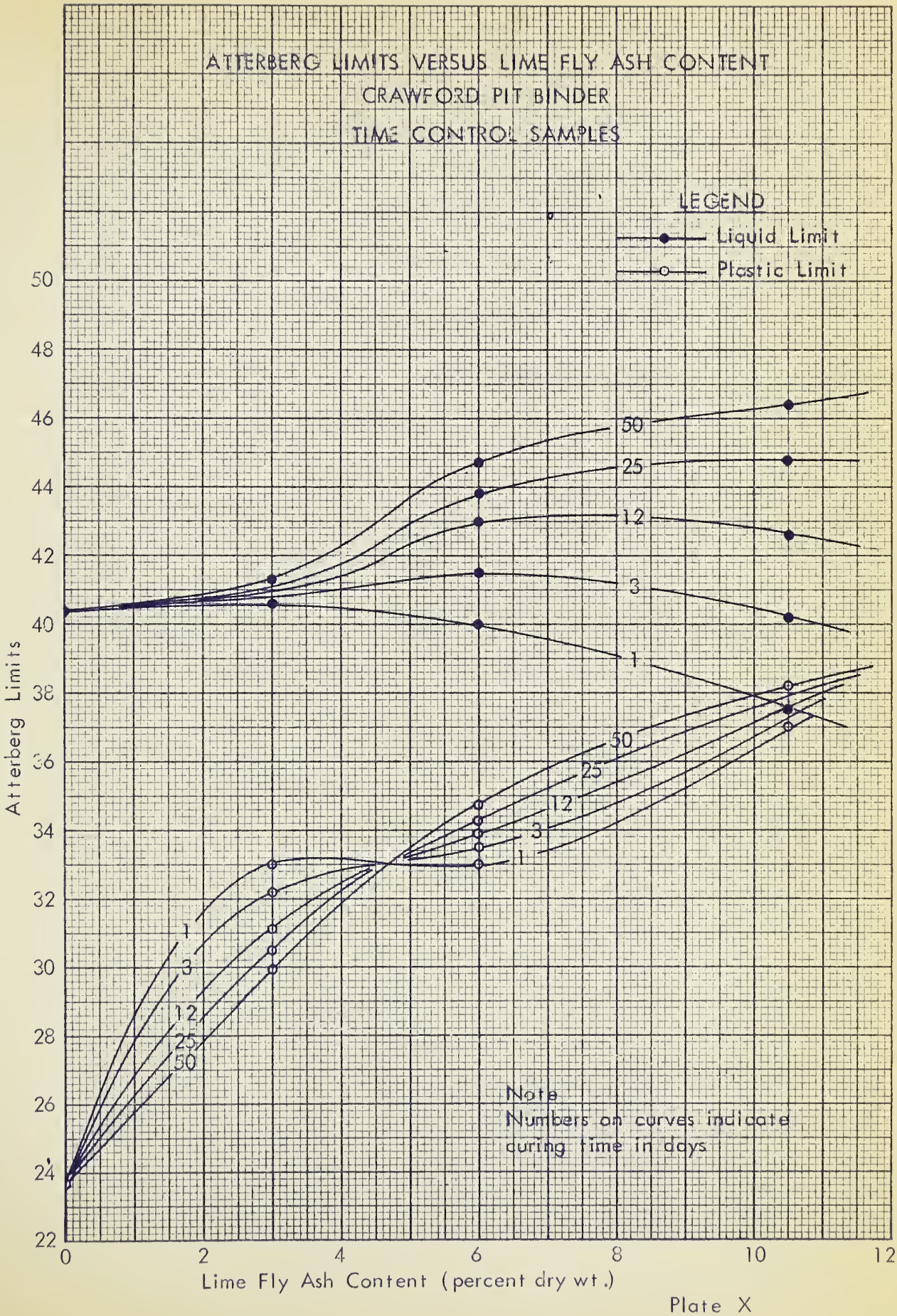

ATTERBERG LIMITS VERSUS LIME FLY ASH CONTENT
CRAWFORD PIT BINDER
TIME CONTROL SAMPLES
LEGEND
Liquid Limit
Plastic Limit
Atterberg Limits
Lime Fly Ash Content (percent dry wt.)
50
25
12
3
1
Note
Numbers on curves indicate
curing time in days

Plate X

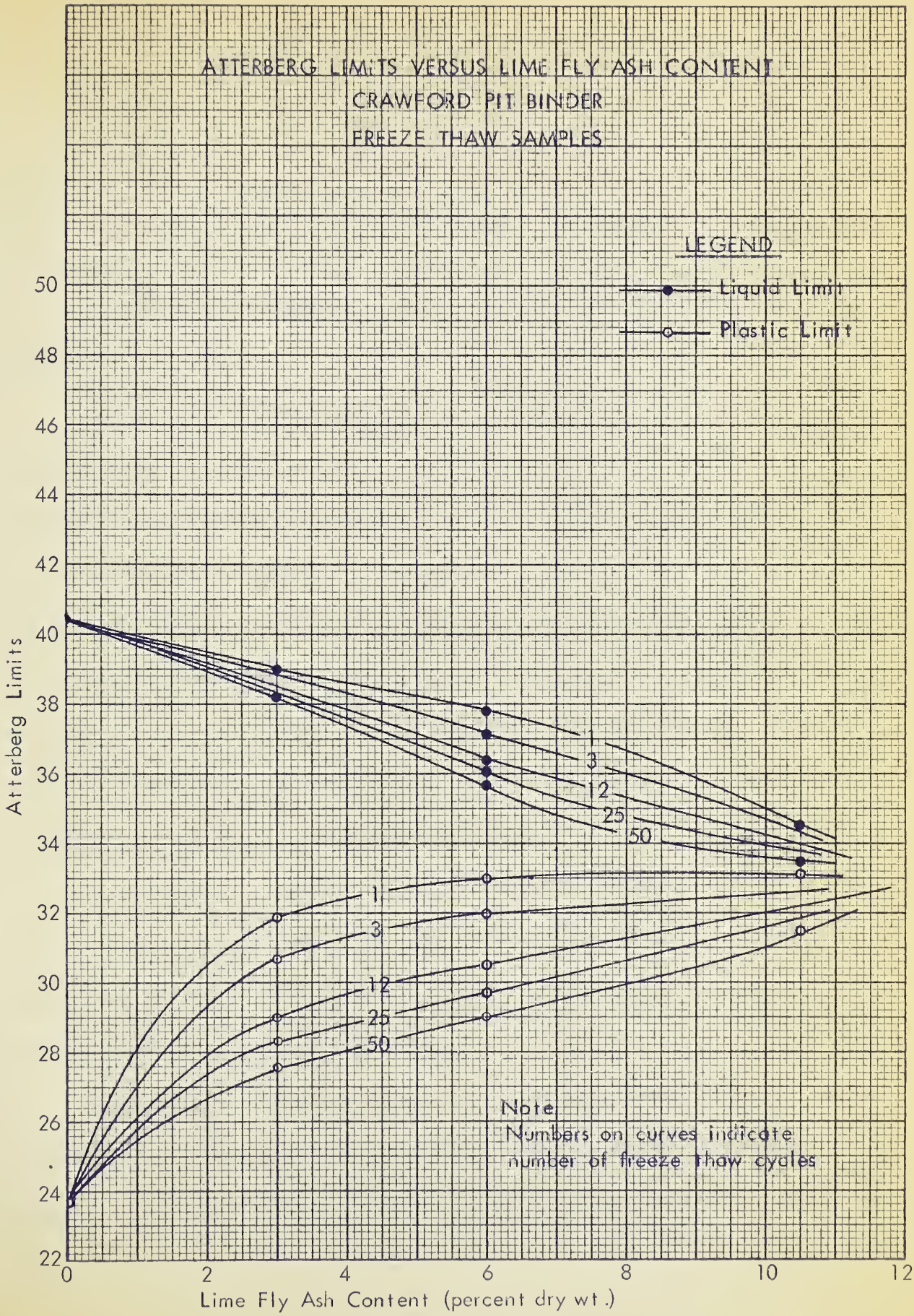

ATTERBERG LIMITS VERSUS LIME FLY ASH CONTENT
CRAWFORD PIT BINDER
FREEZE THAW SAMPLES
LEGEND
Liquid Limit
Plastic Limit
Atterberg Limits
Lime Fly Ash Content (percent dry wt.)
1
3
12
25
50
Note:
Numbers on curves indicate
number of freeze thaw cycles

Plate XI

## CHAPTER V

## DISCUSSION OF RESULTS

From a perusal of the data in form "B" several facts are immediately apparent.

The first one is the magnitude of the experimental errors. In spite of rigid adherence to a standard test procedure and careful control of all variables that would reasonably be expected to influence the results, some fairly large obvious experimental errors are apparent. These errors are attributed to the very nature of the material and the Atterberg Limit test itself. It will be seen that in practically all cases the plasticity index was less than 10. In other words there was a very narrow range of moisture content between the liquid and the plastic limit. The material tended to be granular and friable and behaved more like a silt.

It was observed that the amount of mixing and working prior to the test had an effect on the results. Working seemed to increase the liquid limit. This same phenomena has been observed by other investigators (6) studying the effects of working or mixing on a pure clay.

The effect here is believed due to the tendency of the material, particularly at the higher additive contents to build up a structure. Considerable effort was required to break down this structure before a limit test could be run.

This fact is in itself highly significant. It means that, in addition to the modification of the clay fraction brought about by the additives, there is also a cementing action and in the undisturbed state the material would possess even better strength characteristics than would be indicated by the Atterberg Limits. Strangely, this tendency to build up a structure was more pronounced in freeze thaw samples. This is believed to be due to the influence of crystal growth and pressure during the freezing process. Baver (7) has shown that during slow freezing large crystals form which serve as growth centers to which water is drawn from around the particles. This dehydration effect in conjunction with the internal pressure causes a more intimate contact between the soil grains and results in an aggregating effect.

Due to the friable nature of the material, it was also difficult to obtain consistent plastic limit results and here in particular operator technique plays a large part. In spite of the difficulties encountered and the inevitable scattering of results, some fairly definite patterns are evident.

The effect of the cement additive will be discussed first and reference is made to the data in form B, Plates II to IV inclusive.

With respect to the time control samples the initial reaction which occurred during the first 24 hours, shown as one cycle on the graphs, was a slight increase in liquid limit and a marked increase in plastic limit. The net result of this change in limits reduced the plasticity index to about

half its original value. The general trend thereafter, as curing proceeded, was toward a slight increase in both liquid and plastic limits, the plasticity index remaining approximately constant.

With respect to the freeze thaw samples the initial reaction resulted in little if any change in liquid limit. The plastic limit increased approximately as it did in the time control samples resulting in a much lower plasticity index, approximately one third its original value. Following the initial reaction as the samples were subjected to repeated freezing and thawing the general trend was toward a slight lowering or drop in both liquid and plastic limits the plasticity index again remaining approximately constant.

The net effect of the cyclic freezing on the samples treated with Portland cement was:

(a) To arrest the initial increase in liquid limit.

(b) Cause a progressive reduction rather than an increase in the numerical value of both liquid and plastic limit as curing proceeded. This trend however is not pronounced.

(c) Due to (a) above, cause a marked reduction of the plasticity index. In all cases the plasticity index of the freeze thaw samples was lower than that of the corresponding time control samples.

Consider now the effects of the lime fly ash additive and refer to Plates V to VIII inclusive. Here, broadly speaking the pattern is similar

but somewhat more complicated. It would appear that different reactions occur at different additive concentrations.

At an additive concentration of 3 percent there was very little difference in behavior of the time control and freeze thaw samples. There was little change in liquid limit. Initially the plastic limit was increased and the plasticity index lowered but there was a discernible tendency for the material to revert to its original state as curing proceeded. Cyclic freezing had little effect except to lower both the liquid and plastic limits very slightly below those of the constant temperature samples.

At an additive concentration of 6 percent the initial reactions were about the same as they were with the 3 percent concentration; the trends however were different. Both the liquid and plastic limits tended to increase when cured at constant temperature and to decrease with cyclic freezing, similar to the reactions observed in the samples treated with Portland cement. The plasticity index of both the freeze thaw and time control samples increased slightly with curing.

When the lime fly ash content was raised to 10.5 percent the reactions were quite different. Initially the liquid limit of the time control sample was lowered and the plastic limit was raised to the extent that the material became non plastic. The freeze thaw sample also became non plastic but the liquid limit was considerably below that of the time control sample. As curing proceeded the plastic limit of the time control sample

remained relatively constant but the liquid limit increased resulting in a progressive increase in the plasticity index. The cyclic freezing caused a very slight increase in liquid limit and a slightdecrease in plastic limit. This resulted in a small increase in plasticity index as the cyclic freeze thaw curing proceeded.

In all cases when the material was treated with the lime fly ash admixture the effect of cyclic freezing was generally to lower both the liquid and plastic limits below the corresponding values of the material cured at constant temperature. With the exception of the material treated with 3 percent lime fly ash cyclic freezing also lowered the plasticity index.

A more comprehensive picture of the inter-relationship between additive content, Atterberg Limits, curing time and number of freeze thaw cycles can be obtained by studying the data as presented in form "C". Consider the effects of the Portland cement first and refer to Plates VIII and IX.

Plate VIII shows the relationships for the constant temperature curing. Here is will be seen that there is a definite increase in both liquid and plastic limits and a reduction of plasticity index with increasing additive content.

For a curing period of 50 days there seems to be a fairly well defined optimum additive concentration at about 7 percent. However for the one day

curing period there appears to be an optimum for the liquid limit only; the plastic limit appears to increase steadily with increasing additive content.

This increase in plastic limit with additive content does not agree with Millions' (2) findings. He concluded that a cement content of 3 percent was the optimum value with respect to plastic limit and little further change occurred beyond this. It should be noted however that Millions drew his conclusions from the results of a series of tests made after a curing period of one hour and these results were heavily weighted with data on additive concentrations between 0.5 and 2.0 percent. Additive concentrations of less than 2 percent were not studied in this investigation however it is considered that Millions' one hour test results can with equal validity be interpreted to show an increase in plastic limit up to a cement content of about 7 percent and that his 24 hour test results (interpolated from Fig. 13C of reference 2) can be interpreted in no other way. The only real divergence therefore is that Millions' data tends to show a peak in the plastic limit versus cement content curve at a cement content of about 7 percent whereas the data obtained in this investigation tends to show a steady increase up to 8 percent and by extrapolation somewhat beyond.

It is unfortunate that data were not obtained for higher additive concentrations but 8 percent was considered the maximum economically feasible for field use.

Refer now to Plate IX which shows the influence of cyclic freezing and thawing on the above described reactions.

Firstly, it must be pointed out that the liquid and plastic limits shown on this plot at zero percent additive do not really belong here because no data were obtained on the influence of cyclic freezing and thawing on the natural material. This was an unfortunate oversight as it is quite possible that cyclic freezing and thawing would have an influence on these values (7). The points have been shown, however, because they complete the picture and more clearly illustrate the effect of freezing.

The net effect of cyclic freezing is to cause a drop rather than an increase in liquid limit. The build-up of the plastic limit is retarded and the material still remains slightly plastic up to a cement content of 8 percent. Extrapolating the curves, it would appear that, at a cement content of about 12 percent the material would become non plastic with a liquid limit of about 34, somewhat lower than for the time control specimens. Caution must however be used in extrapolating these curves to predict the material's behavior beyond an additive concentration of 8 percent because in all probability at higher cement contents a definite cementing action would become the most significant result of the treatment, particularly in an undisturbed material and the Atterberg Limits could not be used to evaluate this. It may be concluded however that from the point of view of modifying

the plasticity characteristics of the minus 40 sieve fraction of this material the efficiency of the treatment diminishes above a cement content of eight percent.

Consider now the effects of the lime fly ash additive and refer to Plates X and XI. It will be seen that the general pattern of the lime fly ash reactions is similar to that of the Portland cement. There are however some important differences.

Initially, in the time control samples, there was a rapid rise in plastic limit as the additive increased to 3 percent and there was practically no change in liquid limit. While this agrees with findings of other investigators (8) the reaction is not permanent and the plastic limit tends to revert with time back toward its initial value. As the additive concentration approaches 4 percent the initial increase in plastic limit becomes more permanent and at concentrations above 4.5 percent the effect of time is reversed, thereafter the plastic limit tends to increase with time for any given additive concentration up to 10.5 percent.

It is interesting to note that the first significant time increase in liquid limit starts to occur at about the same additive concentration that causes the reversal of the time effect on the plastic limit. Clearly then 4 percent is the minimum quantity of lime and fly ash that should be used if permanent results are to be achieved.

An investigation of the physio-chemistry of these reactions was beyond the scope of this project but Yoder (15) states that the action of lime in a soil may be divided into three distinct reactions:

(a) Alteration of the water film structure surrounding the clay particles.

(b) Coagulation (aggregation) of the particles.

(c) Reaction of the lime with soil components to form new chemical compounds.

It is quite possible that a transition from reaction (a) to reaction (b) accounts for the changes that seem to occur at a lime fly ash concentration of about 4.5 percent.

It is also interesting to note that, at an additive concentration of 10.5 percent, the material initially was practically non plastic with a liquid limit of about 37.5. The effect of time was to increase the liquid limit, the plastic limit remaining at about the same value. In other words, the plasticity index will increase with time. A review of the literature indicates that generally the liquid limit of materials treated with lime and fly ash admixtures decreases with curing time. However, Goecker et al (9) report data on eight different soils, two of which, a silty clay loam and a silty clay showed an increase in liquid limit with time when treated with lime-fly ash admixture. Yoder (15) reports that the addition of lime will

cause the liquid limit of silty soils to increase and that of clayey soils to decrease. It would seem therefore, that the behavior of the liquid limit is somewhat erratic and depends on the nature of the particular soil.

It is again unfortunate that data were not obtained at a higher additive concentration, particularly with this additive because the curves are of such a nature that they cannot be readily extrapolated beyond 10.5 percent but it is worth noting that the plastic limit curves appear to be converging and would come to a point at an additive concentration of about 12 percent. Should they actually come to a point, then there is no way of predicting what they would do beyond that point. On the other hand, the tendency to converge is not pronounced and may simply be an optical illusion caused by inaccuracies in the data. They may then run approximately parallel and at about the same slope to intercept respectively the 1, 3, 12, 25 and 50 cycle liquid limit curves. In other words, the material would, with increasing additive become non-plastic with a progressively higher liquid limit.

In turning now to the influence of cyclic freezing and thawing on these lime and fly ash reactions, it will be seen immediately that the net effect, as with the cement, is a marked lowering or reduction of liquid limit with increasing additive content up to 10.5 percent. The build-up or increase in plastic limit is also retarded. It appears that a lime-fly ash content in

excess of 5 percent would be required to achieve a significant and permanent beneficial effect.

It would seem, from the shape of the curves, that the effect of cyclic freezing and thawing on both the liquid and plastic limits is going to be reversed at a lime-fly ash concentration above 11 percent. From the data available, however, it is not possible to predict what the limit values are going to do.

# CHAPTER VI

## SUMMARY OF RESULTS

The significant findings derived from part A of this investigation and which are applicable to the minus No. 40 sieve fraction of the Crawford pit material are summarized briefly in the following paragraphs. The pertinent numerical values can best be obtained from Plates VIII to XI inclusive.

1. The Portland cement additive;
    (a) increased the liquid limit
    (b) increased the plastic limit
    (c) decreased the plasticity index.

2. The effect of cyclic freezing and thawing on the material treated with cement was;
    (a) to lower the liquid limit
    (b) to cause a smaller increase in plastic limit
    (c) to cause an even larger decrease in plasticity index.

3. Curing, both at constant temperature and by cyclic freezing and thawing;

   (a) augmented the changes in liquid and plastic limit described in (1) and (2) above

   (b) caused little change in the plasticity index over and above the initial reactions.

4. The initial action of the lime fly ash additive was to;

   (a) cause a slight reduction of liquid limit

   (b) increase the plastic limit

   (c) lower the plasticity index.

5. Curing at constant temperature modified the initial reactions described in (4) above as follows:

   (a) It caused the liquid limit to increase well above its original value.

   (b) It caused a reduction in plastic limit when the additive content was less than 4.5 percent and an increase in plastic limit at higher additive concentrations.

   (c) It caused the plasticity index to increase.

6. Cyclic freezing and thawing of the material treated with lime and fly ash;

   (a) lowered the liquid limit well below its original value

(b) resulted in a smaller increase in plastic limit.

7. The optimum cement content was approximately 7.0 percent by dry weight of the minus No. 40 sieve fraction.

8. There was no well defined optimum lime fly ash content but concentrations in excess of 5.0 percent were required to achieve significant and permanent results.

9. Portland cement concentrations in excess of 7 percent or lime fly ash concentrations in excess of 10 percent caused a pronounced aggregating or granulating effect that was even more noticeable in the freeze thaw samples.

10. Development of a cementing action was evident in the samples containing the highest concentrations of both additives during the early stages of curing.

So far the discussion has been limited to the effects of the additives used and the modifying influence of cyclic freezing and thawing. It would now be well to consider these effects in relation to the suitability of the material as a sub base.

# CHAPTER VII

## APPLICATION OF THE RESULTS

There are two broad concepts or philosophies behind the use of lime-fly ash or Portland cement additives in sub base or base course materials. One is simply to modify a sub-standard granular material. The primary objective here is to alter the material in such a way as to eliminate its undesirable characteristics. For example, to lower its plasticity index sufficiently to bring it into the realm of suitable material for the purpose at hand. In this way the latent strength of the natural material can be developed under environmental conditions that would otherwise make it unsuitable.

The second and most common philosophy is the field of soil cement. Here the main objective is to increase the bearing capacity of a material by the incorporation of additives that will, through chemical bonds, develop a definite cementing action. In materials of the type under investigation the transition from modification to cementation is not sharply defined and is largely a matter of the quantity of additive used. This study deals primarily with the former use, that is to modify a sub-standard clayey aggregate so that it can be used as a sub base material.

Highway Engineers have long recognized that the liquid limit and plasticity index of the soil fraction of a soil-aggregate mixture have an

important influence on the suitability of a material as a sub base (10). To quote from Ref.10 "Under average conditions of drainage and compaction, the value of a material as a sub grade may be considered to vary inversely as the Group Index." The Group Index is given by the following empirical formula:

$$\text{Group Index} = 0.2a + 0.005\,ac + 0.01\,bd$$

Where:

a = That portion of the percentage of the material passing the number 200 sieve in excess of 35 but not exceeding 75 expressed as a whole number from 1 to 40.

b = That portion of the percentage of the material passing the number 200 sieve in excess of 15 and not exceeding 55 expressed as a whole number from 1 to 40.

c = That portion of the liquid limit greater than 40 but not exceeding 60 expressed as a whole number from 1 to 20.

d = That portion of the plasticity index greater than 10 but not exceeding 30 expressed as a whole number from 1 to 20.

It will be seen that the group index is a function of the following three main variables:

1. The percentage passing No. 200 sieve.
2. The liquid limit.
3. Plasticity index.

To quote again from the Committee Report (10), "The weighing and adopted critical ranges of the variables represent the best judgement of the committee based on a study of average relative evaluations placed on sub grade materials by several highway organizations which use the tests involved in the system."

It was shown in Chapter I that both the quantity and the quality of the fines or minus No. 200 sieve fraction of a soil-aggregate mix have an important and interrelated influence on stability. However, since this study is concerned primarily with the relative influence of liquid limit and plasticity index on the suitability of the material as a sub base, we can ignore for the moment the influence of the percentage of material passing the No. 200 sieve.

A high liquid limit is generally considered objectionable as it is indicative of high compressibility. This is reflected in the Civil Aeronautics Classification System (10) and particularly in the Corps of Engineers, Airfield Classification System (13) where a liquid limit of 50 is considered to be the dividing line between high and low compressibility.

A high plasticity index is usually indicative of poor shearing strength characteristics with respect to changes in moisture content. To illustrate this,

consider a hypothetical base course aggregate devoid of binder or minus number 40 sieve material. Two binder materials are available for blending. Both have a liquid limit of 40 but (a) has a plasticity index of 20 whereas (b) has a plasticity index of 5 percent. Consider two mixes both containing the same percentage of binder but mix (a) contains binder (a), whereas mix (b) contains binder (b). Now consider the shearing strength characteristics of the two mixes with respect to increasing moisture content.

As the moisture content of the binder of material (a) rises beyond 20 percent the binder will begin to lose its binding properties and act as a lubricant (12). This usually causes a reduction in both the cohesion and the angle of internal friction of the material with consequent loss of shearing strength. The binder of material (b) will perform its function satisfactorily up to a moisture content of 35 percent and even beyond this will not have the same lubricating properties. A high plasticity index is also indicative of large volume changes with respect to changing moisture content (11), a characteristic undesirable in a sub base material.

Shearing strength is generally considered a more important factor than compressibility in a sub base material for the simple reason that it is usually placed in relatively thin layers; the object being to spread the load and transmit it at lower intensity to the weaker material below.

That the preceding concepts, developed primarily for fine-grained soils, can still be applied in a qualitative way to soil aggregate mixtures

has been shown by Deklotz (12). He found a definite correlation between the quantity "D" times the percentage of fines in the mix and the California Bearing Ratio. The quantity "D" is defined:

$$D = \frac{\text{Plasticity Index}}{\text{Liquid Limit}} \times 100$$

It has been shown that the Atterberg Limits of the fine fraction are a useable criteria with which to judge the suitability of a granular material and that the criteria will apply to the material under study; a plastic clayey, gravel mixture. It should, therefore, be possible to use these criteria in a qualitative way to evaluate the influence of cyclic freezing and thawing on Crawford pit gravel treated with various quantities of Portland cement and lime fly ash admixtures. These points are brought out in order to clarify the reasoning or philosophy behind this investigation and bring the conclusions that may now be drawn into their proper context.

# CHAPTER VIII

## CONCLUSIONS

1. In all cases, with the exception of the 3 percent lime-fly ash concentration, the effect of cyclic freezing and thawing was to lower, numerically, both the liquid limit and the plasticity index with reference to the corresponding control samples cured at constant temperature. Using these values as criteria, then it can be concluded that cyclic freezing and thawing has a beneficial modifying influence on Crawford pit material treated with lime-fly ash or Portland cement.

2. On the basis of the assumptions stated in Chapter I it can be concluded that the improvements in shearing strengths observed by Clark and Millions or at least the part thereof attributable to the modification of Atterberg Limits will not be destroyed by cyclic freezing and thawing.

A word of caution is necessary here. A distinction must be made between cyclic freezing and thawing and frost action. The chemical modifications of the material are not destroyed by freezing, in fact they are enhanced. This does not mean that the material is not susceptible to "frost action" or ice segregation. The susceptibility of the material to ice segregation was not investigated.

3. The optimum cement content from the point of obtaining maximum permanent modification of the material under investigation is approximately 7 percent by dry weight of the minus No. 40 fraction.

4. The optimum lime and fly ash content is not well defined but quantities in excess of 5 percent will be required for permanent beneficial modification of the material. The optimum content is probably about 10.5 percent.

# PART B

## A STUDY OF THE PERMEABILITY OF PLASTIC CLAYEY GRAVELS AND THE INFLUENCE OF ADDITIVES THEREON

## CHAPTER IX

## CLASSIFICATION AND ANALYSIS OF MATERIAL INVESTIGATED

Two materials were used in this part of the investigation:

(a) Minus three inch material from Crawford Pit.

(b) Minus three inch material from Winger Pit.

The Crawford Pit material was classified in part "A" of this investigation. Detailed analysis of the various dry sieved fractions used in the permeability tests are shown in appendix C.

The laboratory prepared gradation used in the permeability tests is shown in Table IV as gradation "B". Gradation "A" was used by Clark (1) and gradation "C" was used by Millions (2) in their triaxial tests. The gradation used in this part of the investigation represents the best obtainable compromise between;

(a) the grading used by Clark

(b) that used by Millions

(c) the gradings obtainable from the dry sieved fractions shown in appendix C.

The Atterberg Limits of the minus No. 40 sieve fraction used in the three investigations were as reported in part "A".

TABLE IV

Mechanical Analysis of Crawford Pit Material

| Sieve Size | Percent Passing (Dry Weight) Grading A | Grading B | Grading C |
|---|---|---|---|
| 3" | 100 | 100 | 100 |
| 1½" | 90 | 91 | 93 |
| 3/4" | 73 | 73 | 75 |
| 3/8" | -- | 54 | -- |
| No.4 | 40 | 40 | 43 |
| No.10 | 25 | 30 | 29 |
| No.40 | 14 | 19.6 | 17 |
| No.200 | 8.9 | 10.0 | 11.2 |

Winger Pit (SW-14-30-1-W5) is located approximately two miles west of Carstairs, Alberta. Visual examination of the material supported by sieve analysis and Atterberg Limit tests placed the material in the "GF" soil group of the Corp of Engineers Airfield Classification System (3).

The AASHO classification (4) was A-2-4 (0).

The laboratory prepared grading of the Winger pit material used in this investigation is shown as Grading "A" in Table V. Grading "B" is the average result of twenty sieve analysis carried out on samples taken throughout the pit by the Alberta Department of Highways and reported by Millions. Grading "C" is the actual grading used by Millions in his triaxial tests on the native material.

TABLE V

Mechanical Analysis of Winger Pit Material

| Sieve Size | Percent Passing (Dry Weight) Grading A | Grading B | Grading C |
|---|---|---|---|
| 3" | 100 | 100 | 100 |
| 1½" | 75 | 75 | 73 |
| 3/4" | 56 | 56 | 56 |
| 3/8" | 44 | -- | -- |
| No.4 | 36 | 36 | 36 |
| No.10 | 31.5 | 31.5 | 33 |
| No.40 | 26.2 | 26.2 | 26 |
| No.200 | 14.3 | 14.4 | 15.0 |

Table VI shows Atterberg Limit values for the minus No. 40 sieve fraction of the material from Winger pit. Under "A" are shown the Limits of the material used in this investigation. Under "B" are the Limits established as average for the pit by the Department of Highways, Province of Alberta and reported by Millions (2), and under "C" are the Limits of the material used by Millions in his investigation.

TABLE VI

Atterberg Limits - (Minus No.40 Sieve Fraction) Winger Pit

| | A | B | C |
|---|---|---|---|
| Liquid Limit | 21.7 | 23.7 | 21.2 |
| Plastic Limit | 15.5 | 15.5 | 12.5 |
| Plasticity Index | 6.2 | 8.2 | 8.7 |

The Atterberg Limit values shown in Table VI vary for the same reasons that were stated in Part "A" in respect to the Crawford pit material.

# CHAPTER X

## DEVELOPMENT OF THE APPARATUS

The apparatus used in this investigation had to be developed specifically for the job at hand. Before the apparatus was designed some preliminary permeability tests were carried out in order to establish the order of magnitude of the permeabilities, the quantities of water and rates of flow that were going to be involved.

The first of these tests was carried out on the minus No.40 sieve fraction of some Crawford pit material using a specimen one inch in diameter and two inches long in a falling head set up. This test indicated that the minus No. 40 sieve fraction, at least when compacted to a moderately high density was practically impervious. With the maximum available head of 48 inches a measurable flow through the specimen could not be established.

The next test was carried out on the minus No. 4 sieve fraction of the same material using a specimen $3\frac{1}{2}$ inches in diameter and 6 inches long compacted by approximately one half standard Proctor effort. This produced a density of 117.1 $lbs/ft^3$. Initial readings indicated that the permeability of the minus No. 4 sieve material at the stated density was approximately $10^{-6}$ cm/sec.

The next in this series of preliminary tests was carried out on the minus 3 inch Crawford pit material that was to be used in the investigation. The main objectives of this test were:

(a) To get some idea of the influence that the 3 inch aggregate was going to have on the permeability and the test in general.

(b) To determine the most practical specimen length since this would control the design dimensions of the permeameter.

(c) To determine if a 12 inch diameter mold was large enough to permit uniform placing of the pit graded minus 3 inch material without excessive aggregate interference. Work done by others (16) indicated that a 19 inch diameter specimen was desirable for material containing 3 inch aggregate.

The permeameter for this test was a mock up apparatus utilizing a 12 inch diameter triaxal test split mold and base plate. The mold was lined with a rubber membrane to prevent leakage and the sample was placed and compacted as for a triaxial test except that the length of the specimen was only 9 inches.

City water as obtained from the tap was used as the permeant. The inlet head was provided by maintaining a free water surface at the top of the mold. The results of tests with this apparatus indicated:

(a) When the sample was compacted to approximately the same density as was used in the test on the minus No. 40 sieve fraction the presence of the minus 3 inch plus No. 4 sieve aggregate had the effect of increasing the permeability considerably to a value of about $10^{-4}$ cm/sec.

(b) A specimen length of 9 inches would be satisfactory for further testing and would provide differential heads large enough to be easily measureable at rates of flow that did not appear to cause any channelling and were also within the range of easy measurement.

(c) A satisfactory specimen could be obtained in the 12 inch mold provided the larger aggregate particles were placed by hand.

In summary these preliminary tests showed that the permeability apparatus to be designed would have to have the following characteristics and capabilities:

(a) It would have to be capable of measuring permeabilities as low as $10^{-6}$ cm/sec. It was reasoned that $10^{-1}$ cm/sec would be the probable upper limit.

(b) Large quantities i.e. 30 or 40 gallons of de-aired distilled water would be required for each test.

(c) The apparatus would have to maintain and measure differential pressures over the range 0.1 to 20 feet of water in order to keep the rate of flow within acceptable and measurable limits.

(d) The minimum practical specimen or "mold" diameter would be 12 inches. A larger diameter would be preferable from the point of aggregate interference although it would be more difficult to obtain uniform compaction and density control.

(e) A requirement indicated by these tests, although not fully appreciated at the time, was that of being able to measure sample deflection or consolidation caused by the seepage forces.

The above requirements dictated that the permeameter would have to be a closed or pressure type unit. It was also reasoned that a closed unit would facilitate de-airing the specimen and obtaining a high degree of saturation.

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# CHAPTER XI

## DESCRIPTION OF THE APPARATUS

The apparatus finally evolved is shown schematically in Figure 1. It consisted of the following major components.

(a) An open copper boiler mounted over a suitable gas burner for the purposes of boiling the feed water or permeant to remove dissolved gasses.

(b) A heat exchanger unit consisting of a wall type steam radiator submerged in a large tank of cooling water. The purpose of the heat exchanger being to cool the permeant to just above room temperature before it entered the apparatus.

(c) A 40 gallon pneumatic header tank equipped with a side arm type water glass. Approximately one inch of kerosene was maintained on top of the water surface at all times to separate the air and water. The top of the tank could be connected to a vacuum source for filling or a source of air pressure when a forced feed was necessary. The tank was equipped with a pressure gauge and was connected to feed the permeameter directly or the constant head tank as desired.

(d) A diaphragm type pressure reducing valve adjustable over the range 2 to 20 psi. The valve was connected to the shop air line and supplied air at reduced pressure to the top of the header tank.

(e) An atmospheric constant head tank mounted on a suitable stand approximately 5 feet above the permeameter bench. The water level in the tank was maintained by a float operated feed valve. Kerosene on top of the free water surface prevented contact between the de-aired permeant and the atmosphere.

(f) The permeameter; which shall be discussed in more detail under a separate heading.

(g) A 20 inch differential mercury manometer. This was used to measure the higher range of differential pressures across the specimen.

(h) A piezometric manometer for the accurate measurement of small differential pressures. This manometer was equipped with a valved cross connection which greatly facilitated flushing and de-airing the piezometer tubes and connections. It was also used to prove the absence of air in the pressure sensing system and to obtain a quick "zero reading" on the mercury manometer.

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(i) A small, one pint capacity, tail water header tank equipped with a thermometer and overflow orifice. The elevation of this tank could be adjusted as desired to control the differential head across the sample when the apparatus was operating under gravity feed. It was always kept above the elevation of the permeameter so that the absolute pressure in the permeameter was never less than one atmosphere.

## THE PERMEAMETER

The permeameter was designed as far as possible to make maximum utilization of available or readily obtainable materials.

The base plate of the 12 inch triaxial test apparatus reported by Clark (1) and Millions (2) was utilized as the base plate for the permeameter. It was modified to the extent of enlarging the porous bronze plate to $11\frac{1}{2}$ inches in diameter and providing an additional static pressure sensing port.

The barrel of the permeameter was machined from standard 12 inch (nominal) by 3/16 inch welded steel pipe. Suitable lugs for clamping the top and bottom were welded on externally.

The top was machined from 1/4 inch structural steel plate. It was drilled and tapped at the center to receive a standard $\frac{1}{2}$ inch pipe nipple. This formed the main inlet port through which also passed the dial gauge stem. One additional static pressure sensing port was provided near the periphery of the barrel.

It is perhaps worth mentioning that a very successful frictionless seal for the dial stem was constructed from a standard 1/4 inch Swedge-lock fitting. The bore of the fitting was drilled out to receive the 1/4 inch steel stem. The tapered cone or wedge was put in backwards and the metal furl replaced with a 1/4 inch neoprene seal ring. The whole assembly was packed with light grease and the cap tightened just sufficiently to bring the seal ring into contact with the stem.

The seal was sufficiently frictionless to operate freely under the influence of the dial gauge main spring and the weight of the stem. It did not leak during any of the testing and withstood pressures up to 35 psi. A two hundred gram weight was balanced on the stem to ensure a firm seating on the specimen and to overcome the ram effect of the internal pressure.

The joints between the barrel and the top and bottom plates were sealed with 1/4" fabric reinforced rubber gasket material. The barrel was clamped to the base plate with four 5/16 inch threaded hook bolts. The bolts were threaded down well past the lugs so that they could also be used to break the wax seal by pushing the barrel away from the base plate.

Hydraulic tests on the permeameter alone with no specimen in place showed that at maximum rate of flow the head loss across the porous bronze plate was too small to be measurable and could, therefore, be neglected. The relatively high friction losses at high rates of flow through the feed lines and

outlet porting in the base plate proved to be a very desirable characteristic. It automatically compensated for changes in permeability and limited the rate of flow through the highly pervious samples. Since the head loss across the sample was measured directly from the up stream and down stream faces where velocity heads could be considered zero the friction loss in the apparatus did not enter into the measurements or computations in any way.

Figure I illustrates the general layout of the apparatus and the manner in which the various components were connected. Figures II to V inclusive are photographs showing the apparatus in operation. Figure VI is a close-up of a sample of the Crawford pit material and shows the wax seal used to seal the sample in the barrel of the permeameter.

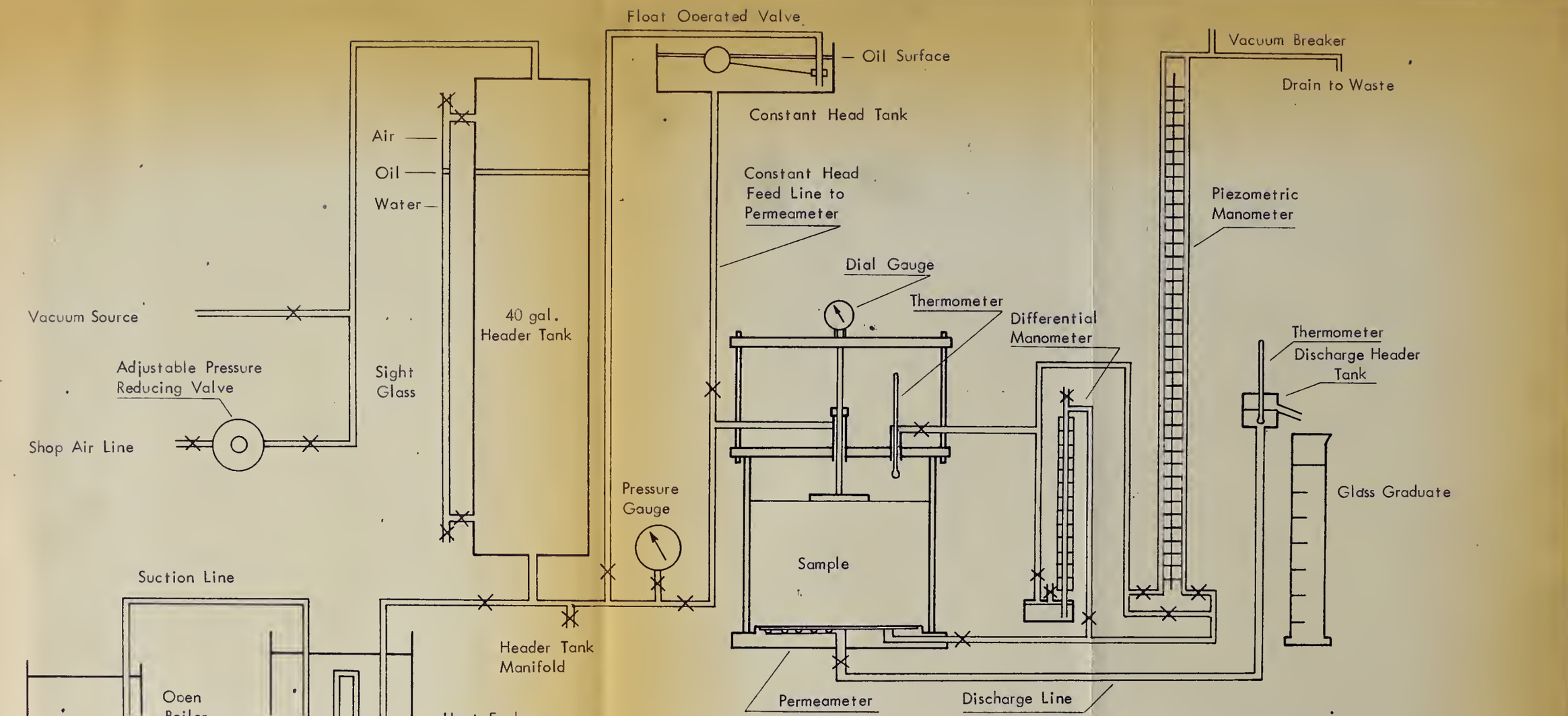
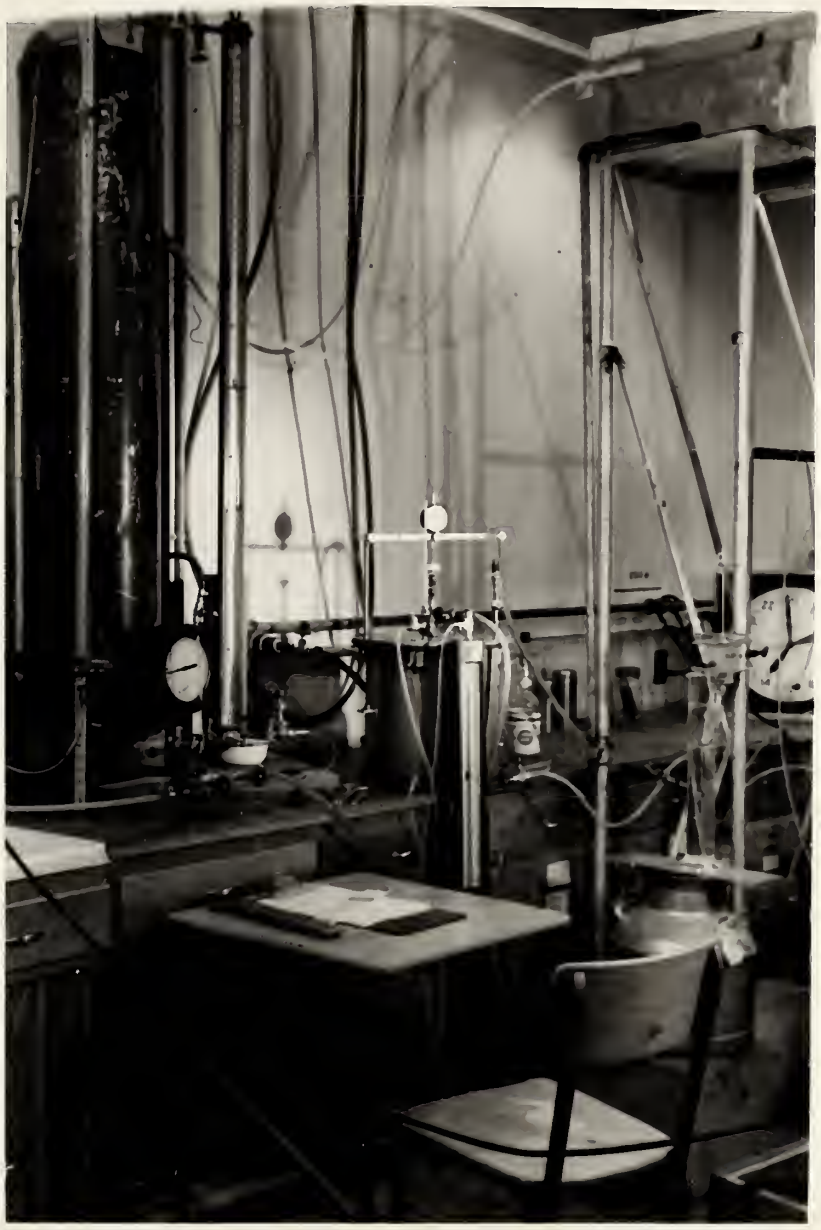



FIGURE 1
SCHEMATIC DIAGRAM OF APPARATUS

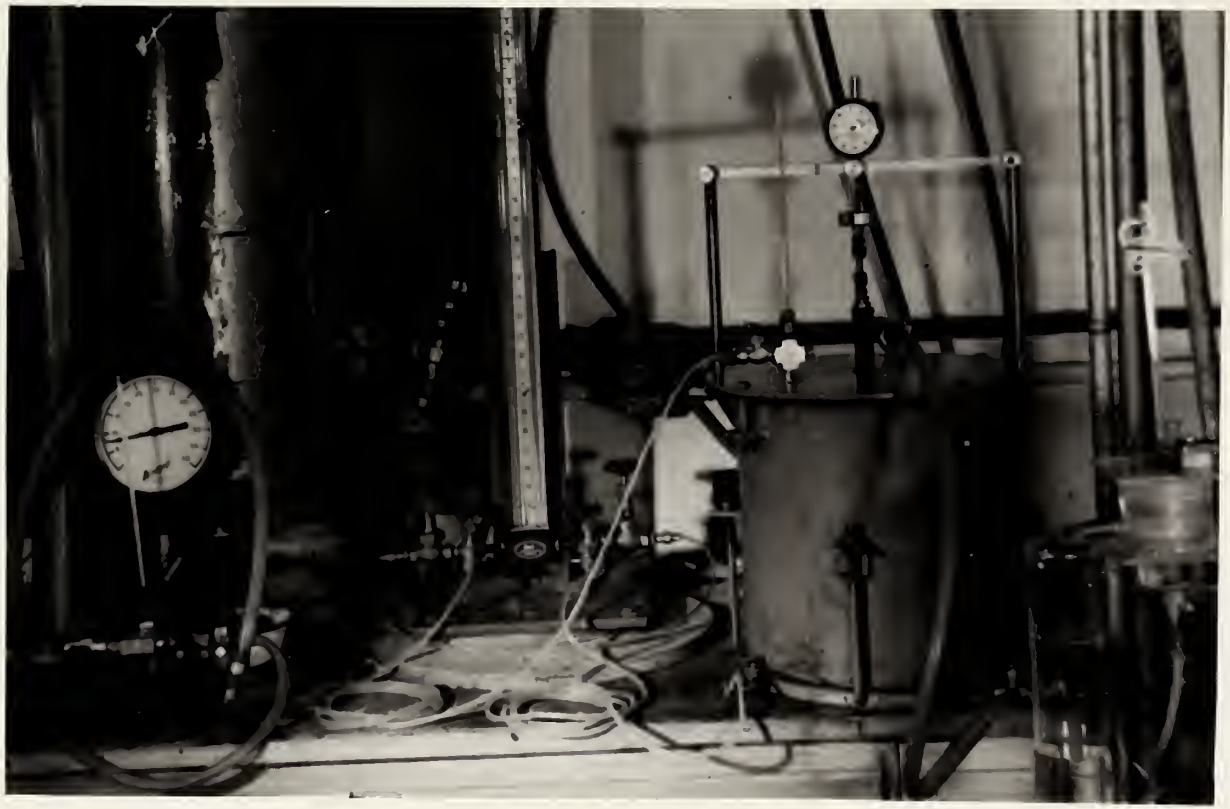


GENERAL VIEW OF THE APPARATUS

Figure II

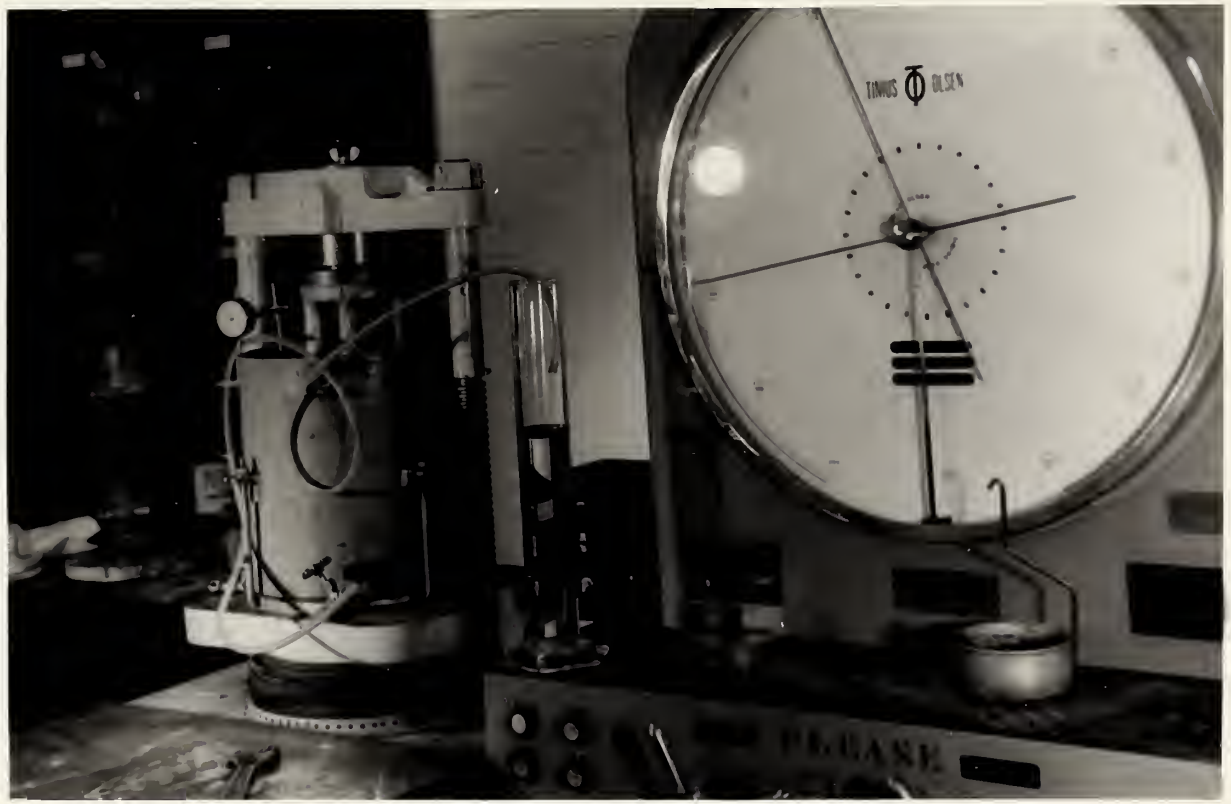
CLOSE-UP OF THE PERMEAMETER ON PRESSURE FEED

Figure III



GENERAL VIEW OF THE PERMEAMETER ON GRAVITY FEED

Figure IV




GENERAL VIEW OF THE STATIC SAMPLE COMPACTION PROCESS

Figure V

CLOSE-UP OF A SAMPLE AFTER REMOVAL FROM THE PERMEAMETER

Figure VI

## CHAPTER XII

## PERMEABILITY TESTING PROCEDURE

The preparation of the pit material into air dried, sized fractions was described in part "A". Both the Winger and Crawford pit materials were prepared in the same way.

A wet sieve analysis was carried out on each of the minus No.4 fractions to determine the true gradation of the fraction and the percentage of material that would "carry over" or be retained on successively finer sieves, down to the No. 200. The hydroscopic moisture content of each fraction was also determined. From these data calculations were made to determine the actual air dry batch weight of each fraction required to produce as nearly as possible the gradations used by Clark and Millions in their investigations.

To prepare a sample for a permeability test the computed air dry batch weights of each fraction were weighed out on a laboratory solution balance. It was rarely possible to obtain exactly the computed weight of the minus 3 inch plus $1\frac{1}{2}$ inch fraction due to the relatively large weight of the individual particles; however, by judicious juggling it was possible to approach the weight very closely and maintain an approximately uniform

gradation. After batching the total air dry weight of the sample was determined and this weighing formed the basis of all subsequent density computations. For this reason every precaution was taken to avoid subsequent loss of material.

The dry material was placed in a small plaster boat, mixed thoroughly and then spread out in a uniform layer. Approximately one half of the computed quantity of distilled water was then spread over the material and mixed in by hand. The process was then repeated adding the remainder of the measured quantity of water and re-mixing. Each sample was mixed by hand for at least five minutes to break up any clay balls and ensure uniform dispersion of moisture. The sample was then cured under wet sacking for a minimum period of 12 hours prior to compaction. The approximate moisture content at which each specimen was initially compacted is shown in the summary test results, Table VII.

Hand mixing was adopted as it was found that mixing in a cement mixer tended to roll the material into a system of clay balls and particles of aggregate coated with clay would become almost perfectly spherical. This structure did not disappear readily upon compaction.

The permeameter specimens were compacted initially in the 12 inch diameter triaxial test split mold used by Clark and Millions. The material was spread out in a uniform layer in the plaster boat and divided into three approximately equal parts. Each part formed one complete lift in

the mold. To ensure uniformity and to avoid segregation or aggregate interference all specimens were placed in this manner regardless of the method of compaction to be subsequently used. As previously mentioned, it was necessary to orient the larger aggregate sizes in each lift by hand. The only exceptions to this procedure were samples No. 1 and No. 2 which were compacted in two rather than three lifts.

Two methods of compaction were used, dynamic and static. All samples up to and including the initial compaction of sample No. 6 were compacted dynamically. All subsequent compaction was carried out by static loading in a Tinius Olsen loading machine.

The samples were compacted dynamically with a modified Marshall hammer developed by Clark. The hammer had a 3 7/8 inch diameter face and the impact was provided by a 10 pound weight falling 30 inches. The first lift received 44 blows, the second 48, and the third 52 blows evenly distributed about the surface. An exception was sample number 5 where the number of blows per layer was doubled.

In the instances where specimens were recompacted dynamically after permeability tests had been run they were compacted in the permeameter barrel and the additional compactive effort was applied to the top surface of the material.

As experience was gained it became apparent that the required precision of density control could not be achieved with dynamic compaction.

The density could be measured quite accurately but it could not be predetermined with the required precision. To overcome this difficulty static compaction was resorted to and proved to be quite satisfactory.

Since the dry weight of the material in the mold was known it was a simple matter to compute the required length or height of specimen in the mold corresponding to any desired density. Static load as required was applied to compact the specimen to this predetermined height.

Static compaction also made it possible to effectively recompact or consolidate in the saturated state in the permeameter. An attempt was made without much success to dynamically recompact samples No.1 and No.2 in this state. While a small increase in density was obtained the main effect was simply to churn up the upper layer of material.

Sample No.6 was the first sample to be recompacted in this manner and it was done rather on a trial and error basis to see how the procedure would work out. The data obtained from this sample served as a guide in controlling the rate of load application in subsequent operations. The rate of loading was controlled by the rate of discharge from the sample such that the hydraulic gradients generated in the sample by the load application would not exceed the gradients to be used in the next succeeding permeability determination.

After initial compaction in the split mold, either dynamically or statically, the mold was removed and the barrel of the permeameter was

lowered carefully over the specimen and clamped to the base plate. The inside diameter of the permeameter was slightly larger than the diameter of the mold. The annular space between the sample and the barrel was sealed with Mikrovan No.1300 sealing wax. Mikrovan No.1300 is a special wax developed by Imperial Oil Ltd. for the food processing industry. It remains soft and pliable at room temperature, has excellent bonding characteristics and is highly impermeable to water.

With the exception of sample number 3 the samples were saturated in the open permeameter from the bottom up with de-aired distilled water. A positive head of between 3 and 6 inches was used for this operation.

Sample number 3 was saturated from the bottom under a vacuum of 0.80 $Kg/cm^2$. Considerable difficulty was encountered in performing this operation and after the experience with this sample the procedure was abandoned.

After the samples had been saturated and a free water surface established above the material a 4 inch diameter coarse porous stone was placed and firmly seated on the specimen directly under the inlet port. This stone served two purposes, to prevent scouring of the sample by the incoming water and to act as a bearing for the dial gauge stem. The permeameter top was then placed into position and clamped very lightly. De-aired water was then admitted through the inlet port to flush all air out of the permeameter. This flushing operation was assisted by tipping the permeameter

gently from side to side. This flow was maintained for several minutes to thoroughly flush out any water that had picked up air prior to the removal of all free air from the permeameter. At this point the top bolts were drawn down and the inlet pressure sensing lines flushed to remove all air.

The outlet pressure sensing lines were flushed by establishing a flow through the sample. In cases where the permeability was too low to accomplish this, the flushing was done by means of an auxilliary feed line from the header tank to the discharge orifice in the base plate.

After these operations had been completed the specimen was allowed to stand under full static inlet head for a few minutes while the initial dial gauge reading was recorded and the manometer zero readings were checked to prove the absence of air in the pressure sensing system. With all in readiness flow was established through the specimen by slowly opening the discharge valve and when the manometers were steady permeability measurements were commenced.

The rate of flow was determined by measuring with a stop watch the elapsed time required to collect a given volume of effluent. While the effluent was being collected observations were made on the differential head, inlet and outlet temperatures and dial gauge readings. From these data and the known dimensions of the specimen the permeability could be computed.

# CHAPTER XIII

## INITIAL OBSERVATIONS

The original purpose of this part of the investigation was simply to measure the permeability of the native material compacted by a standard laboratory procedure and then to see what influence various percentages of Portland cement and lime-fly ash admixture would have thereon. The programme had not proceeded very far before it became apparent that some major unaccounted variables were involved and a presentation of specific results without first discussing the manner in which they were developed would be quite misleading. An attempt will therefore be made to outline chronologically the manner in which the investigation was conducted, the major difficulties encountered and the action taken to overcome them. A summary of results will be presented at the conclusion of this discussion.

Since no standard procedure exists for tests of this nature it was necessary to develop both an apparatus and a suitable laboratory technique or test procedure. The apparatus had been fairly well perfected at the conclusion of test number 3 on the Crawford pit material but a standard procedure in all its minor aspects had not been evolved until the completion of test number 6. Therefore, throughout these early tests both the procedure

and the apparatus were varied and modified as necessary in an attempt to overcome the various unforseen problems as thevarose. Such a process led inevitably to some large experimental errors and scattering of results. Making due allowance for this and disregarding results known to be in error certain trends seemed to appear and attempts were made either to control or evaluate the variables thought to be responsible.

At the conclusion of test number 2 the following trends could be detected:

(a) Small increases in density, admittedly in conjunction with much sample disturbance, caused a very marked drop in permeability.

(b) At the given initial density there appeared to be an increase in permeability during the first few minutes of flow and thereafter a persistant drift toward lower and lower values.

It was suspected that this drift in the coefficient of permeability was being caused by air in the soil voids but, due to the setup of the apparatus the inlet head and the head loss across the sample were also changing while the test was in progress and this could have been the cause. Test number 3 was, therefore, set up to determine the cause of this apparent drift in permeability.

Prior to setting up test number 3 the apparatus was modified to include constant head feed and constant head discharge devices. In setting

up the test every precaution was taken to eliminate all possible sources of air in the apparatus and the sample was saturated under maximum obtainable vacuum in order to achieve a high initial degree of saturation.

Test number 3 showed this same reduction of permeability with time of flow or permeation and this quite conclusively eliminated air or variations in head as the cause. It was then reasoned that consolidation of the specimen under hydraulic gradient was the cause. The following observations lent emphasis to this theory:

(a) The material tended to regain some of its permeability during periods of rest.

(b) A plot or graph of permeability versus log of time of flow showed an almost perfectly characteristic consolidation time curve. This is shown in Plate XII.

The permeameter was, therefore, equipped with a dial gauge mounted in such a way as to permit observation of sample deflection or settlement under hydraulic stress. A test was set up and a flow maintained at constant head and approximately constant temperature continuously for 41 hours while periodic readings were taken on the permeability and the settlement of the specimen. The data thus obtained was plotted against log time of flow. This plot is shown on Plate XIII. Again the characteristic "S" shaped permeability versus log time curve was obtained and there appeared to be

a definite correlation between sample deflection and permeability. It should be noted that these results were obtained on a specimen that had been subjected to permeability tests off and on for the preceding eight days and de-aired distilled water had been forced through it under various heads for an aggregate total of 54 hours prior to this run. The drop in permeability with time was not as pronounced as in the initial testing but it was still clearly in evidence.

Taken at face value evidence of this nature would certainly indicate a correlation between permeability and settlement. However, it seemed inconceivable that a change in void ratio of 0.37 percent could account for such a large change in permeability. It was reasoned that if in fact the permeability was sensitive to minute changes in void ratio then the same correlation should exist independent of the time rate of change of void ratio. In other words, if the void ratio were forced to change over the same range in a very short period of time by altering the hydraulic gradient then the same changes in permeability should occur. The weakness in this argument was the assumption that permeability would be independent of hydraulic gradient. The weakness notwithstanding, it was decided to try this and see what would happen. Another test was, therefore, run on sample number 3 in which the hydraulic gradient was varied over a wide range in a short period of time and observations were made on dial reading and permeability.

The results of this test are shown graphically on Plate XIV together with the data from the constant head test. The following conclusions can be drawn from this plot:

(a) The decrease in permeability was a function of time of permeation.

(b) The small decreases in void ratio that were observed under constant head occurred co-incident with but were not the cause of the changes in permeability.

(c) For the given density and test conditions the permeability did not vary widely with changes in hydraulic gradient but there was a detectable tendency for the permeability to decrease with increasing head loss. This may have been due to any one or a combination of the following:

(i) A progressive transition to a turbulent flow condition in some of the larger voids.

(ii) The change in void ratio. Although this change in void ratio was still very small (0.5 percent) so was the change in permeability.

(iii) The inevitable time or permeation effect.

Had the gradient been progressively reduced back to its starting value, and observations made during the process, the effect of permeation may have been apparent. However, this was not foreseen until after the test had been completed.

During test number 3 PH readings were taken periodically on the effluent to see if there was any measurable change in PH co-incident with the change in permeability. It was later determined that the meter being used was out of order and, therefore, the data obtained were useless.

At the conclusion of test number 3 a moisture content determination was made on some of the discarded material and the degree of saturation was computed to be 94 percent. It was however exceedingly difficult to obtain an accurate final moisture content due to the large aggregate and also the rapid migration of moisture as the material was removed from the permeameter barrel. The computed degree of saturation may not therefore be highly accurate.

Thus far in the programme little had been accomplished. The permeability of the native Crawford pit material was now known to be an exceedingly evasive quantity that varied over a wide range and seemed to depend on many variables not all of which were understood.

Lambe (17) in his work on fine grained soils reported a similar phenomena, that is a decrease in permeability with permeation. The following paragraph taken directly from his paper is his explanation of the phenomena:

"The reduction in permeability that occurs with permeation is caused by a change in structure. As flow through the soil occurs, particles tend to move to positions of higher stability to seepage forces. This particle shifting always results in a lower permeability if the particles are not washed

out of the soil. While this particle shifting can result in either an increase or decrease in density or saturation degree, it usually causes a densification and higher degree of saturation. The permeability reduction has to be explained, therefore by changes in structure rather than incidental changes in density or degree of saturation."

This explanation was not entirely accepted at the time for two reasons:

(a) Lambe was using compressed nitrogen directly in contact with the permeant to establish the inlet head. He also had a small negative outlet head. It was, therefore, considered that his observed decrease in permeability may have been caused by the evolution and retention of gaseous nitrogen in the void space at the lower end of the specimen.

(b) It did not entirely explain the partial recovery of permeability during periods of rest.

Thinking on the latter point has since been revised. It seems entirely reasonable that when the seepage forces are removed a random drifting or dispersion of the colloidal particles occurs and results in an increase in permeability.

While the decrease in permeability with permeation had not been entirely explained it was decided to carry on and see what effect the additives would have and also to see how the Winger pit material would behave.

Accordingly, tests number 4 and 5 were run on the Crawford material and tests number 1 and 2 were run on the Winger material.

The results obtained from these tests indicated;

(a) that the native Winger pit material behaved in the same manner as the Crawford material, the permeability of both decreasing as a function of the time of permeation

(b) that the additives did not have any major influence on permeability

(c) that there was a correlation between the PH of the effluent and permeability

(d) that the density of the specimens, known to affect permeability, was not being controlled with sufficient precision to make direct comparisons between test results.

During the test on the Winger material reliable PH readings were obtained on the effluent at intervals throughout the test. These data are shown graphically in Plate XV. There appeared to be a definite correlation between the change in permeability and the change in PH. This data is offered as evidence, but not proof, that some physio-chemical action may be responsible at least in part for the persistant tendency of the permeability to decrease with duration of flow.

Plate XVI shows another interesting phenomena that occurred during this test as a result of an error in procedure and illustrates the sensitivity of the test results to minor disturbances of the soil. This was the first test

in which the mercury reservoir type differential manometer was used and some difficulty was experienced in getting all the air out of the reservoir. During this operation the specimen was inadvertently subjected to one or two abrupt fluctuations of pressure which resulted in some structural disturbance as evidenced by a murky effluent. The effluent cleared up a few minutes after steady flow conditions had again been established.

As shown on the graph the initial reaction was an immediate increase in permeability by a factor of about two. It was thought at the time that the specimen had been ruined by channelling or piping and the test was continued mainly to try out the new manometer. When this had been done the permeameter was switched back to gravity feed and allowed to run overnight. The data obtained completed the tail end of the now familiar permeability time curve. This data has been presented mainly as an illustration of the sensitivity of permeability test results to seemingly minor disturbances.

In spite of the discontinuity in the test results and the questionable reliability of the latter portion of this particular permeability time curve there does appear to be a correlation between permeability and PH.

This immediately raised the question of the purity of the feed water and the possibility that some part of the apparatus or the oil used therein was contaminating the feed water. Accordingly a sample of the feed water was submitted to Mr. C. Emerson Noble, Provincial Analyst, University of Alberta. His report is shown in Appendix E. It was reasoned that the feed

water did not contain sufficient impurities to so greatly affect the permeability. The cause of the change in PH was not, therefore, determined.

At this point a decision had to be made whether to pursue further the possibility that physio-chemical reactions were responsible for the changes in permeability or whether to carry on with the program as originally envisioned.

Since this investigation was concerned primarily with permeability from the point of view of pore pressure dissipation in a sub base under dynamic loading and since a sub base would not normally be subjected to the severe leaching or permeation effects inherent in the permeability test it was reasoned that the time dependent variations in permeability could for the purposes of this investigation be ignored. Pursuit of the former cause would have been exceedingly interesting if only from an academic point of view, but actually would have been far beyond the scope of this investigation. It was decided, therefore, to carry on and see if any useable correlations could be established on the basis of initial permeability readings only.

On the basis of initial readings only the results so far clearly illustrated the importance of density in its effect on permeability. It was also apparent that the required precision of density control was not being achieved with dynamic compaction. It was reasoned that if static compaction were used the desired control could be achieved and that a series of permeability tests could be run on a given specimen at several different densities. This would establish a permeability versus density curve for a given sample and with a

family of these curves the influence of the additives could be studied. This approach also had the advantage of conserving the rapidly dwindling supply of prepared material.

Test number 6 was the first test in which static compaction was used and was therefore somewhat experimental.. However, tests number 7, 9, 11, 12 and 13 were run on statically compacted samples using a standard procedure throughout. Test number 8 was run for a special purpose that will be discussed later. Throughout this latter phase of the program the duration of flow through the specimen was kept to a minimum. The results achieved in this phase of the investigation are shown in Table VII. It should be noted that the coefficients of permeability shown in Table VII are initial values only and do not take into consideration the major changes caused by permeation.

TABLE VII

Summary of Permeability Test Results

| Sample No. | Additive | Method of Compac. | M.C. %D.W. | Dry Density lb/ft$^3$ | Void Ratio | Final Degree of Saturation % | Permeability at 20°C cm/sec |
|---|---|---|---|---|---|---|---|
| | | | Crawford Pit -3" Material | | | | |
| 1 | | Dyn. | 8.20 | 119.6 | 0.41 | | $2.66\times10^{-2}$ |
| | | " | | 125.1 | 0.34 | | $1.98\times10^{-5}$ |
| 2 | | Dyn. | 8.13 | 123.1 | 0.36 | | $8.91\times10^{-3}$ |
| | | " | | 128.2 | 0.31 | | $4.37\times10^{-4}$ |
| 3 | | Dyn. | 8.06 | 127.0 | 0.32 | 94 | $2.48\times10^{-4}$ |
| 4 | 3% L.F.A. | Dyn. | 9.50 | 130.3 | 0.29 | 93 | $6.04\times10^{-5}$ |
| 5 | | Dyn. | 7.67 | 131.6 | 0.27 | | $4.88\times10^{-6}$ |
| 6 | | Dyn. | 7.0 | 117.5 | 0.43 | | $1.08\times10^{-2}$ |
| | | Static | | 120.9 | 0.39 | | $8.37\times10^{-5}$ |
| | | " | | 123.2 | 0.36 | | $1.70\times10^{-5}$ |
| | | " | | 126.2 | 0.33 | | $3.84\times10^{-6}$ |
| | | " | | 129.5 | 0.29 | | $8.20\times10^{-7}$ |
| 7 | | Static | 6.5 | 118.1 | 0.42 | | $4.58\times10^{-3}$ |
| | | " | | 123.5 | 0.36 | | $4.50\times10^{-5}$ |
| | | " | | 129.8 | 0.30 | | $5.98\times10^{-6}$ |
| 8 | | Static | 11.5 | 123.5 | 0.36 | | $1.40\times10^{-4}$ |
| | | " | | 131.0 | 0.28 | | $1.81\times10^{-7}$ |
| 9 | | Static | 6.5 | 118.5 | 0.42 | | $1.19\times10^{-2}$ |
| | | " | | 121.2 | 0.36 | | $4.79\times10^{-4}$ |
| | | " | | 128.5 | 0.31 | | $1.87\times10^{-5}$ |
| 11 | 0.5% N.P.C. | Static | 7.63 | 120.5 | 0.39 | | $8.45\times10^{-3}$ |
| | " " | " | | 126.1 | 0.33 | | $2.79\times10^{-4}$ |
| | " " | " | | 130.1 | 0.29 | 96 | $1.94\times10^{-5}$ |
| 12 | 1.5% L.F.A. | Static | 9.3 | 120.5 | 0.39 | | $5.46\times10^{-3}$ |
| | | | | 125.2 | 0.34 | | $5.57\times10^{-4}$ |
| | | | | 129.7 | 0.29 | 90.5 | $5.06\times10^{-5}$ |
| 13 | | Static | 7.0 | 119.2 | 0.41 | | $7.24\times10^{-3}$ |
| | | | | 122.1 | 0.37 | | $1.32\times10^{-4}$ |
| | | | | 126.5 | 0.33 | | $9.18\times10^{-6}$ |
| | | | | 130.2 | 0.29 | 86.0 | $1.91\times10^{-6}$ |
| | | | Winger Pit Material | | | | |
| 1 | | Dyn. | 6.0% | 141.0 | 0.19 | | $6.47\times10^{-5}$ |
| 2 | 3% L.F.A. | Dyn. | 6.0% | 134.0 | 0.25 | | $4.63\times10^{-4}$ |
| | | " | | 135.0 | 0.24 | | $9.57\times10^{-5}$ |

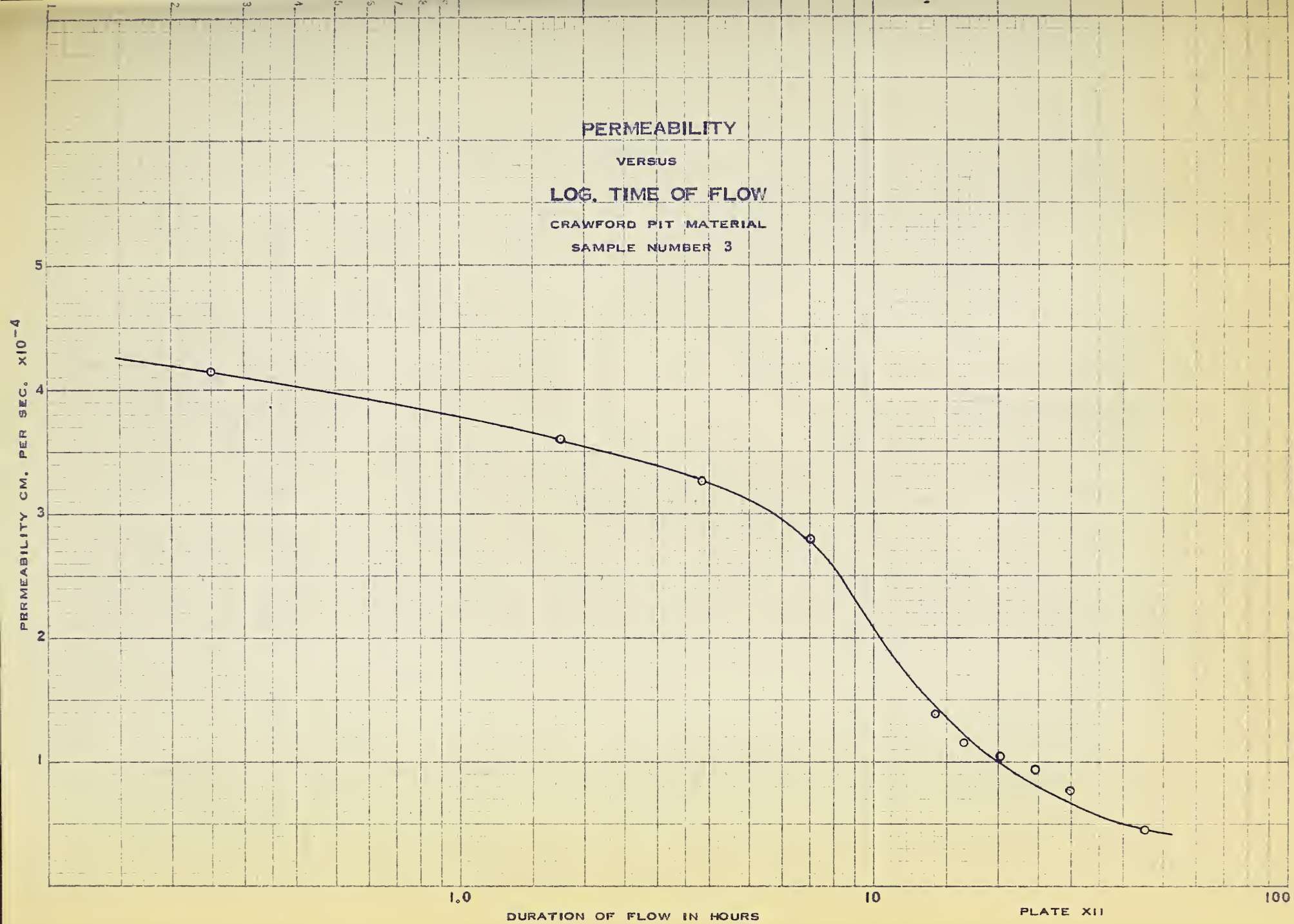
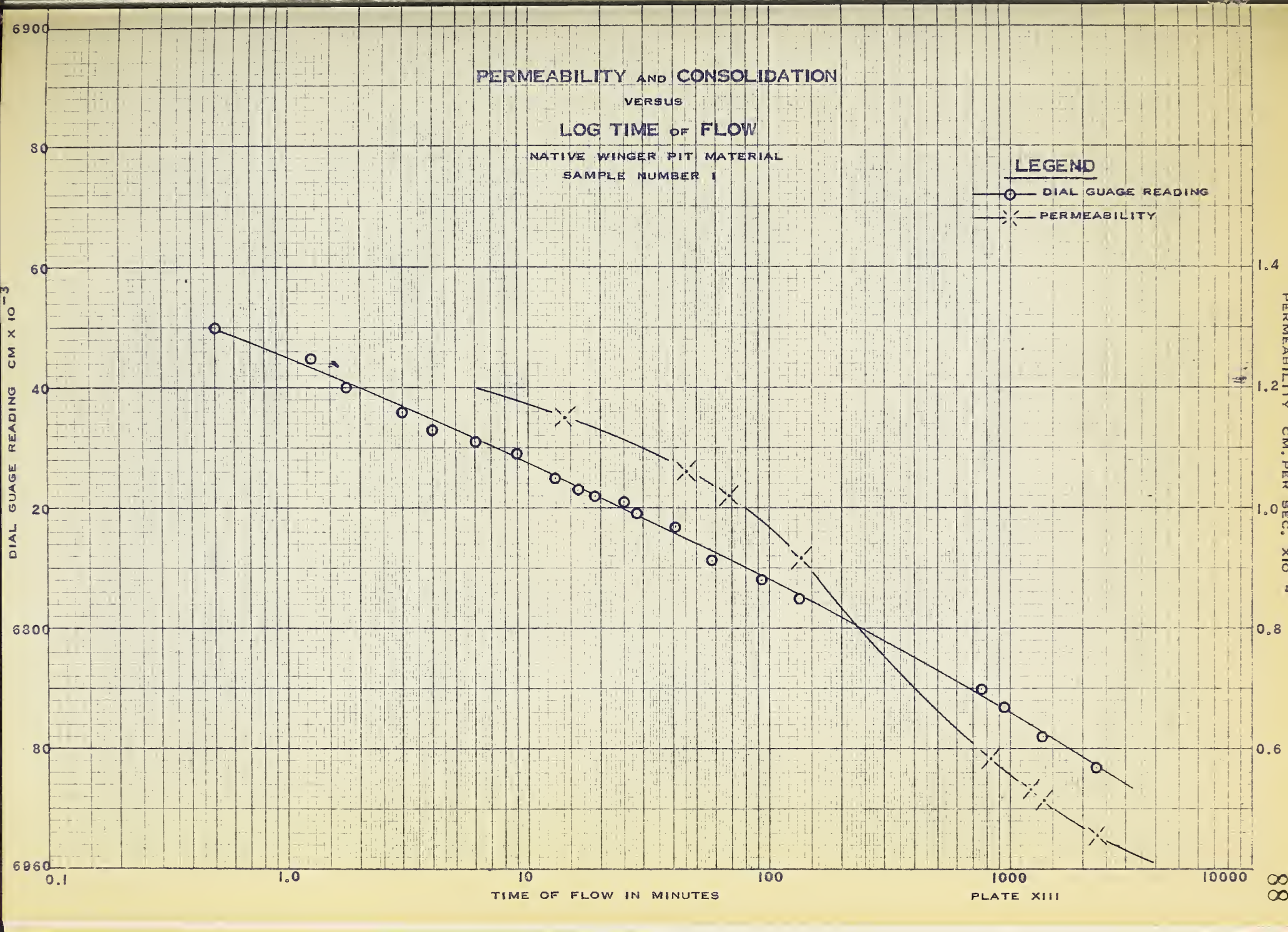

PERMEABILITY
VERSUS
LOG. TIME OF FLOW
CRAWFORD PIT MATERIAL
SAMPLE NUMBER 3
PERMEABILITY CM. PER SEC. X10⁻⁴
5
4
3
2
1
1.0
10
100
DURATION OF FLOW IN HOURS

PLATE XII


PERMEABILITY AND CONSOLIDATION
VERSUS
LOG TIME OF FLOW
NATIVE WINGER PIT MATERIAL
SAMPLE NUMBER 1
LEGEND
DIAL GUAGE READING
PERMEABILITY
DIAL GUAGE READING CM X 10⁻³
6900
80
60
40
20
6800
80
6960
1.4
1.2
1.0
0.8
0.6
PERMEABILITY CM. PER SEC. X10⁻⁴
0.1
1.0
10
100
1000
10000
TIME OF FLOW IN MINUTES
PLATE XIII

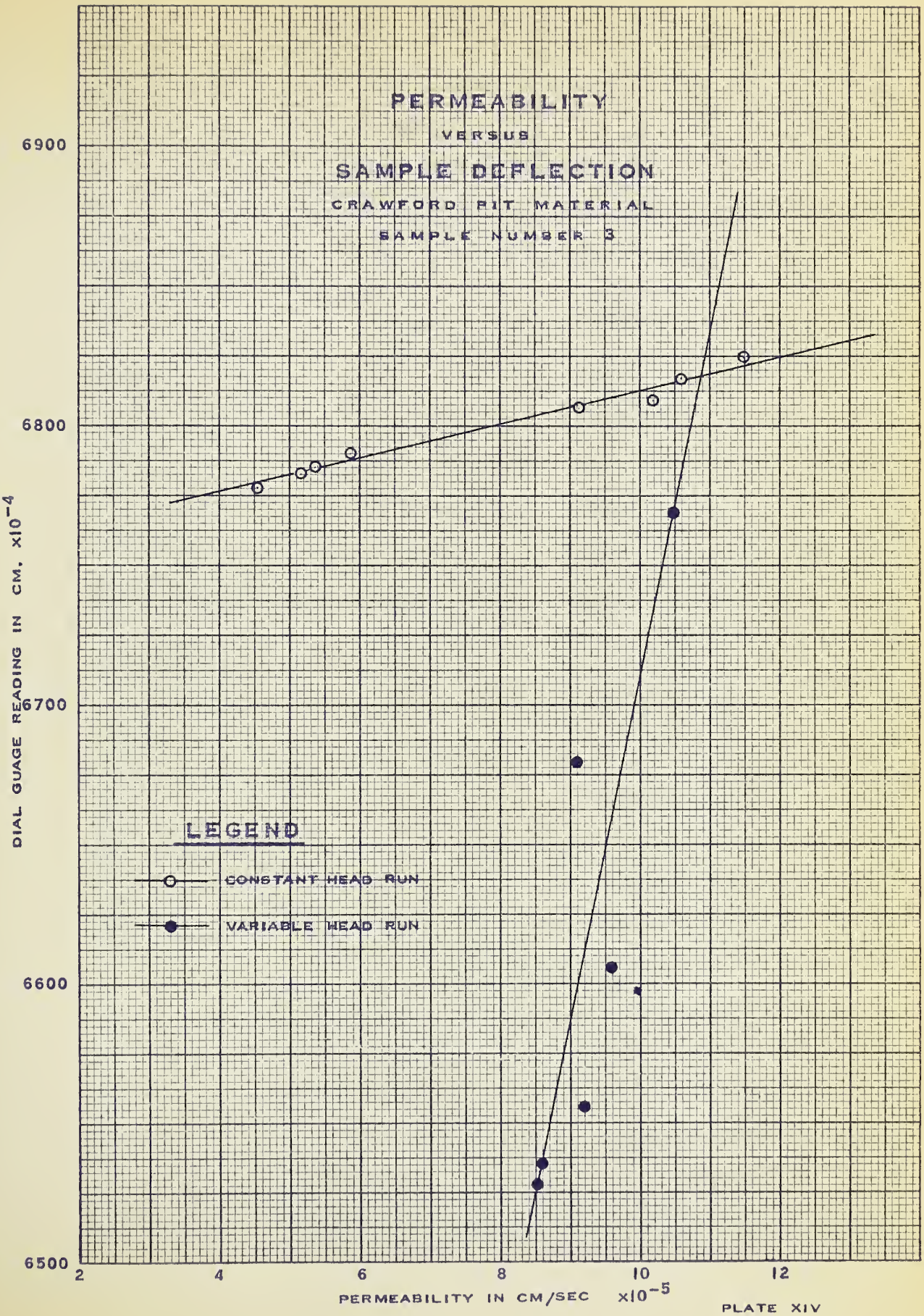

PERMEABILITY
VERSUS
SAMPLE DEFLECTION
CRAWFORD PIT MATERIAL
SAMPLE NUMBER 3
6900
6800
6700
6600
6500
DIAL GUAGE READING IN CM. x10⁻⁴
LEGEND
CONSTANT HEAD RUN
VARIABLE HEAD RUN
2
4
6
8
10
12
PERMEABILITY IN CM/SEC x10⁻⁵

PLATE XIV

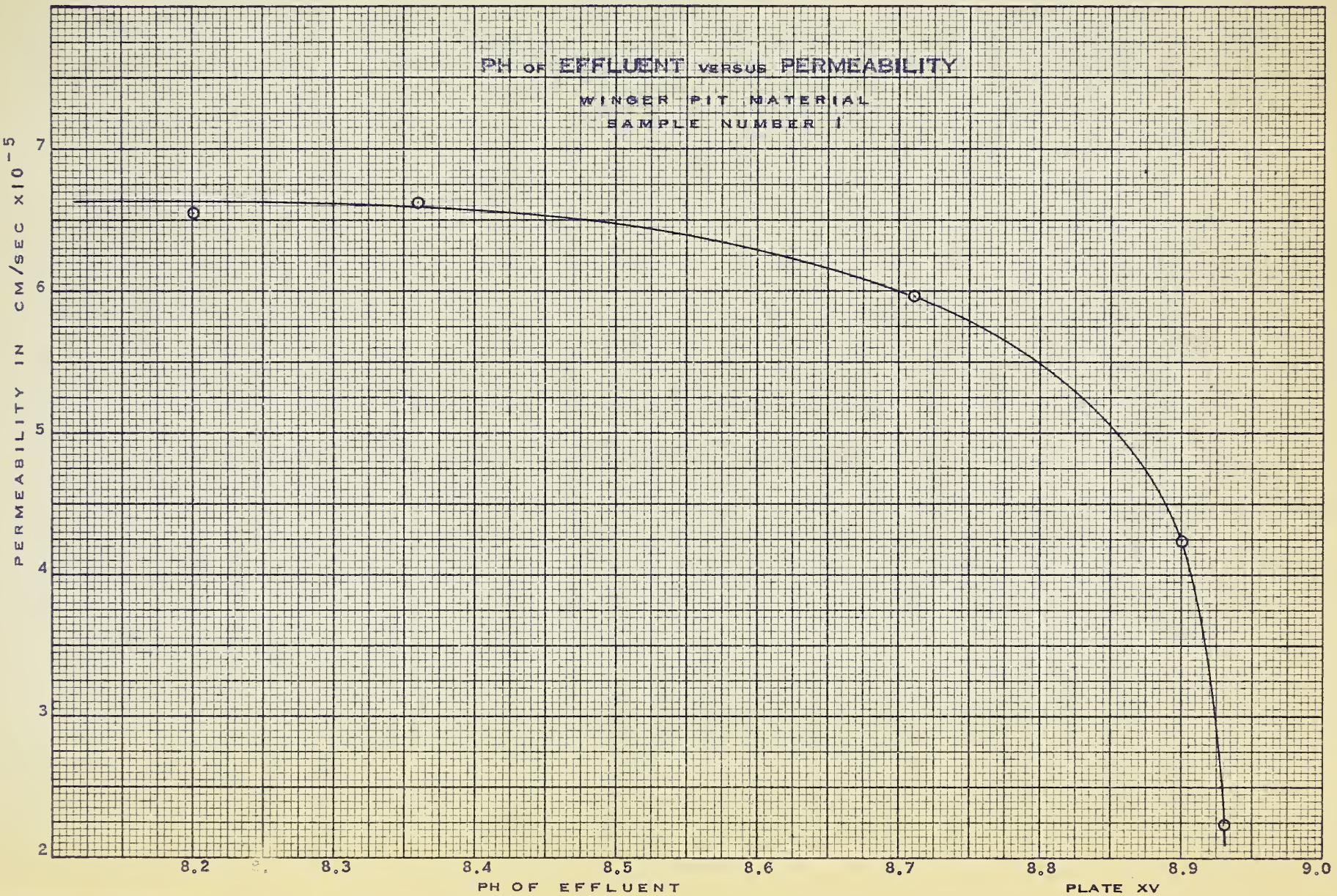

PH OF EFFLUENT versus PERMEABILITY
WINGER PIT MATERIAL
SAMPLE NUMBER 1
PERMEABILITY IN CM/SEC X10⁻⁵
7
6
5
4
3
2
8.2
8.3
8.4
8.5
8.6
8.7
8.8
8.9
9.0
PH OF EFFLUENT

PLATE XV

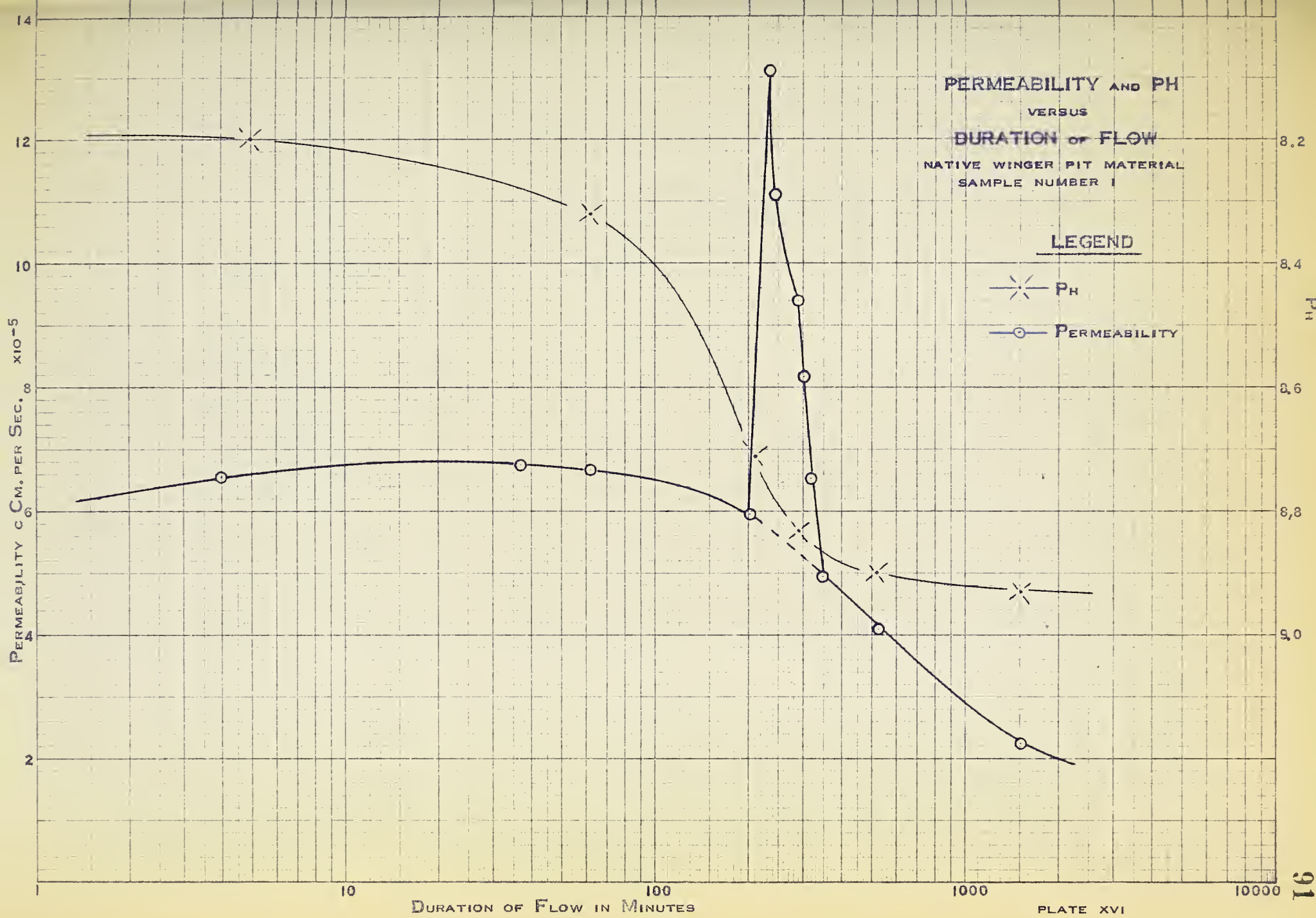
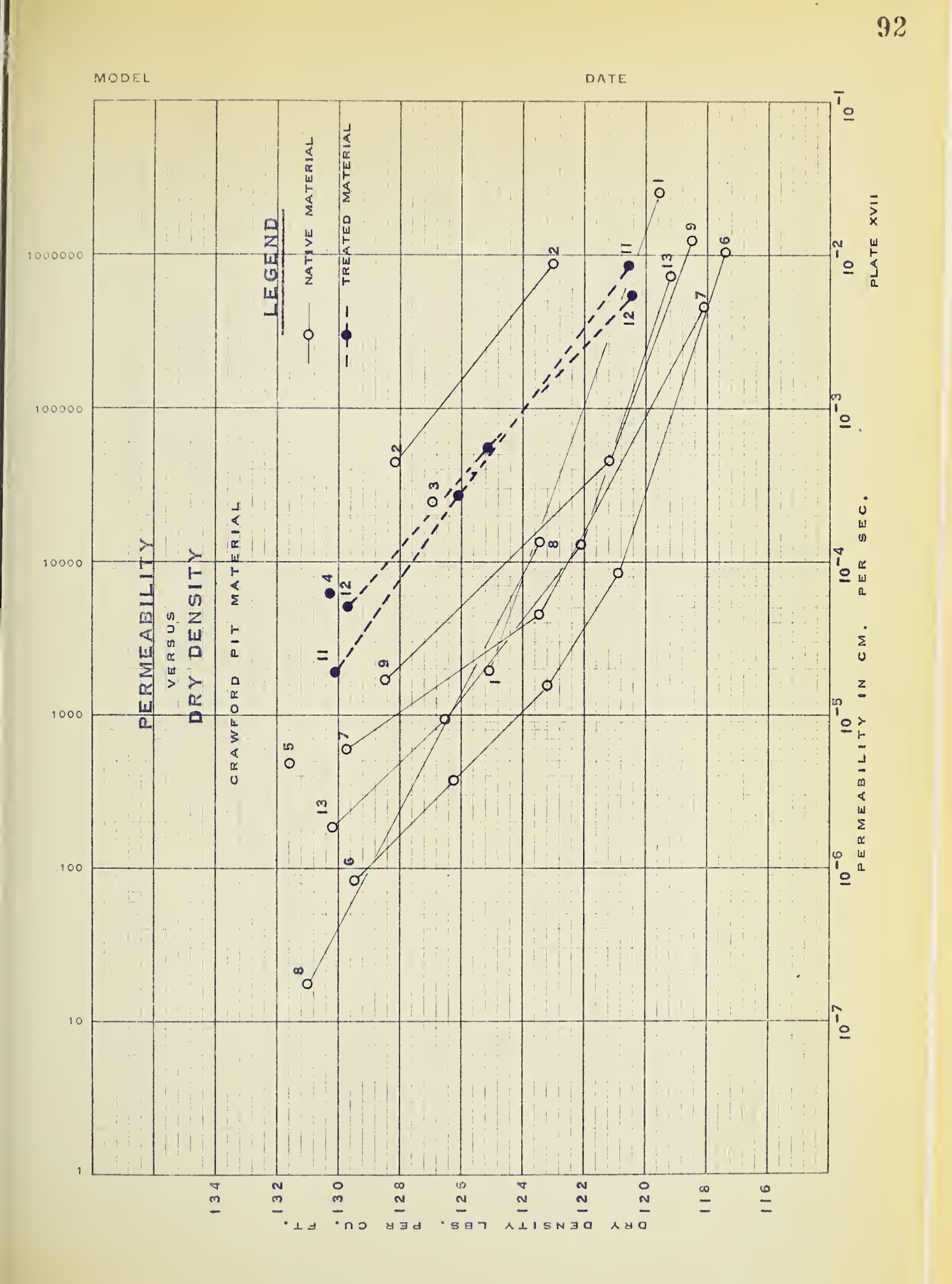

PERMEABILITY AND PH
VERSUS
DURATION OF FLOW
NATIVE WINGER PIT MATERIAL
SAMPLE NUMBER 1
LEGEND
PH
PERMEABILITY
PERMEABILITY c CM. PER SEC. X10-5
PH
DURATION OF FLOW IN MINUTES
14
12
10
8
6
4
2
8.2
8.4
8.6
8.8
9.0
1
10
100
1000
10000

PLATE XVI


MODEL
DATE
PERMEABILITY
VERSUS
DRY DENSITY
CRAWFORD PIT MATERIAL
LEGEND
NATIVE MATERIAL
TREATED MATERIAL
PERMEABILITY IN CM. PER SEC.
DRY DENSITY LBS. PER CU. FT.
1000000
100000
10000
1000
100
10
1
$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^{-4}$
$10^{-5}$
$10^{-6}$
$10^{-7}$
134
132
130
128
126
124
122
120
118
116
PLATE XVII

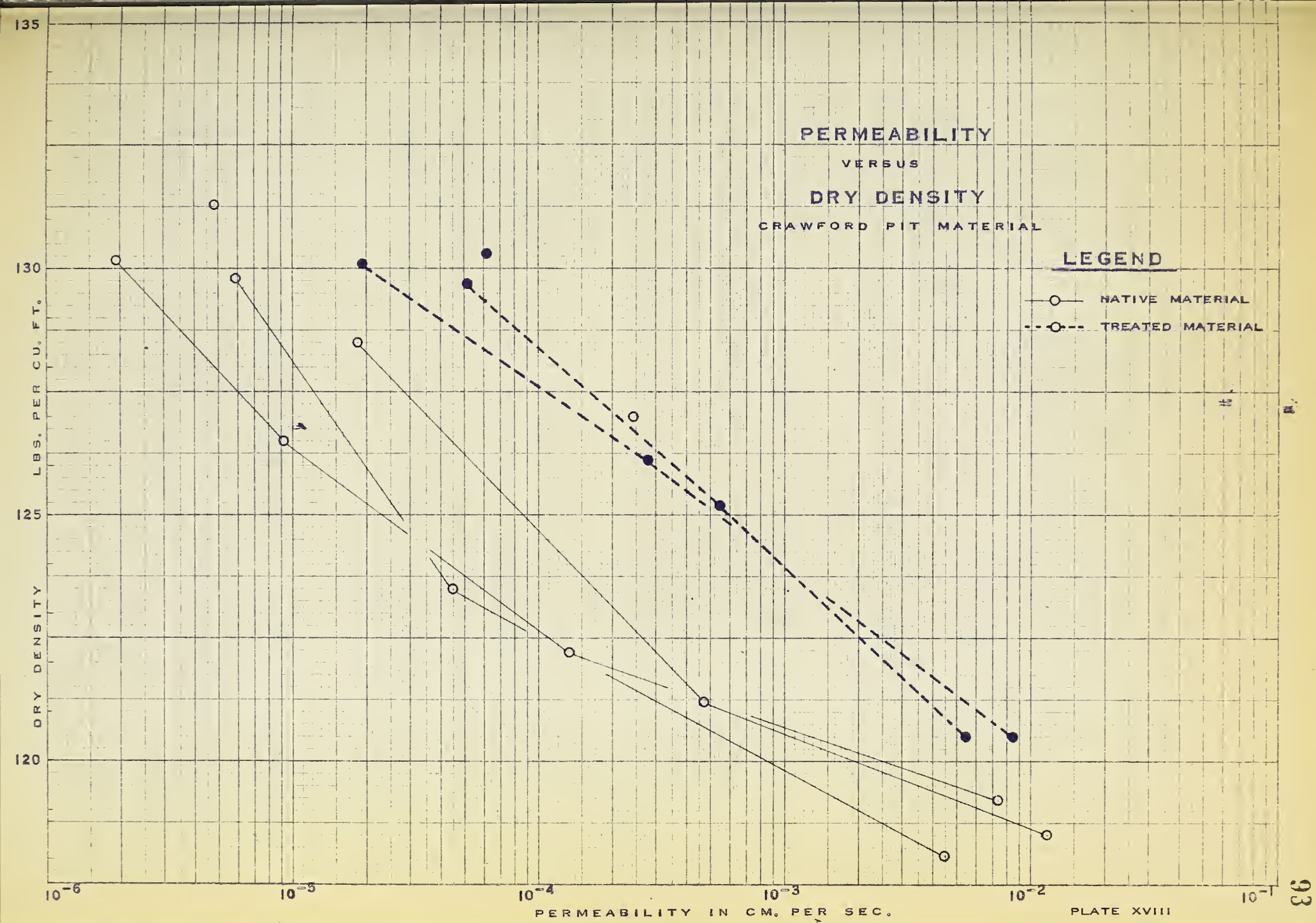

PERMEABILITY
VERSUS
DRY DENSITY
CRAWFORD PIT MATERIAL
LEGEND
NATIVE MATERIAL
TREATED MATERIAL
DRY DENSITY LBS. PER CU. FT.
135
130
125
120
$10^{-6}$
$10^{-5}$
$10^{-4}$
$10^{-3}$
$10^{-2}$
$10^{-1}$
PERMEABILITY IN CM. PER SEC.

PLATE XVIII

## CHAPTER XIV

## DISCUSSION OF RESULTS

For comparitive purposes the data presented in Table VII are shown graphically in Plate XVII. The most striking feature of this plate is the extreme range in numerical values of the coefficient of permeability of untreated Crawford pit material. The values ranged from $2 \times 10^{-2}$ to $2 \times 10^{-7}$ cm/sec. depending primarily on the density and method of test. It will also be noted that the test densities were all within a fairly narrow band; the minimum being 117.5 lbs/ft$^3$ the maximum 131.6 lbs/ft$^3$. While these results are admittedly erratic they are perhaps not entirely beyond reason.

Now it is known that some of the results shown on Plate XVII are unreliable for various reasons already stated. If the data of questionable reliability are eliminated and the graph is redrawn using only those data that were obtained with standardized test procedure and which are considered reasonably reliable the picture becomes much less confusing. These data are shown on Plate XVIII.

Very little literature has been published on permeability test results where useable numerical data are given and generally when such data are given they are applicable to a material of relatively narrow gradation or range

in grain size. However, Burmister (18) has shown that the greater the range in grain size distribution the greater the influence of relative density on the coefficient of permeability.

He did not report on any materials with a gradation quite like that of the Crawford pit material used in this investigation. The maximum aggregate size in his widest gradation was 3/4 inch. He did not report the plasticity characteristics of the fine fraction but from his reported grain size distribution it can be inferred that the fines were predominately silt and, therefore, non plastic. In other words the maximum spread in grain size in the material used by Burmister was considerably smaller than the spread in the Crawford material. Using this material he observed the permeability to range from $6 \times 10^{-4}$ to $3 \times 10^{-6}$ cm/sec; a ratio of approximately 200 in going from a relative density (5) of 1.0 to 99 percent.

It will be seen from Plate XVIII that the average permeability of the untreated Crawford pit material varied from $7 \times 10^{-3}$ to $6 \times 10^{-6}$, a ratio of approximately 1000, in going from a dry density of 118.5 to 129.5 lbs/ft$^3$. The range in permeability was somewhat greater but so was the range in grain size. It is considered, therefore, that the data shown on Plate XVIII are not entirely unreasonable.

From a study of Plate XVIII the influence of the additives can be clearly seen. Generally, for a given density, the treated material had a

coefficient of permeability roughly ten times greater than the untreated material. However, in view of the overall range in permeability this difference is not really very large.

There appeared to be little difference between the influence of the Portland Cement and the lime-fly ash additives at a concentration of 0.5 percent* by dry weight of minus three inch material. This corresponds to an additive concentration of 2.8 percent with respect to the dry weight of the minus number 40 sieve material. The lime-fly ash additive showed a slightly steeper permeability density curve but this could well be attributed to experimental error.

It would perhaps have been desirable to run a few tests at higher additive concentrations, but the results of test number 3 on the natural material and test number 4 on material containing a 3 percent concentration** of lime-fly ash admixture indicated that little additional benefit would be derived.

The permeability-density curves for the untreated material reveal an interesting feature. When the material was compacted or consolidated in the saturated state there was a marked drop in permeability with the first small increase in density and thereafter the change in permeability with density was less pronounced up to the maximum density obtained. This is exactly opposite

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* Unless otherwise stated in this discussion all additive concentrations are expressed as a percentage of the dry weight of the minus 3 inch material.

** This corresponds to a concentration of 11.1 percent when expressed as a percentage of the dry weight of the minus No. 40 sieve fraction.

to the effects observed by Burmister (18) and the reason is believed to be the influence of, and changes that occur in, the soil structure as a result of different testing procedures and also slightly different soils.

In Burmister's tests the soil was placed and compacted in the dry state and saturated from the bottom under full vacuum. This procedure, as will be seen later, should minimize the influence of structural changes that are believed to occur after the process of saturation.

There is considerable evidence both in this investigation and in the work reported by Lambe (17) that soil structure is an important variable and can, other factors being constant, have a major influence on permeability.

The existence of a soil structure was apparent very early in this investigation. It was for this reason that mechanical mixing in the concrete mixer was rejected because it tended to roll the fines into a system of spheres. Even after hand mixing, close examination of the material revealed the existence of a structure in the fine fraction when mixed at any moisture content below 10 percent. Below this moisture content the fines had a flocculent or aggregated structure somewhat similar to the "nugget" type structure often observed in weathered clays and this structure was still in evidence even after the material had been compacted. This structure was attributed to aggregation by capillary forces in the clay fraction of the fines and it was reasoned that it would disappear upon saturation.

As soon as the static compaction procedure had been adopted and tests number 6 and 7 completed a fundamental difference could be observed

in the permeability density curves established by:

(a) tests number 6 and 7

(b) tests number 3, 4, 5 and the initial points of 6 and 7.

At the time a change in structure was suspected to be the cause and in an attempt to prove this sample number 8 was mixed and placed at a moisture content of 11.5 percent where the structure seemed to disappear. The material was rodded and worked in the mold deliberately to obtain thorough dispersion of the fines.

The initial permeability of sample number 8 at a dry density of 123.5 $lbs/ft^3$ fell very close to the line established by samples number 6 and 7 which at this density had been disturbed, i.e. recompacted in the saturated state. This was taken as evidence of the influence of soil structure.

It is believed that the difference in the permeability density curves established by different test procedures can be explained on the basis of changes in structure and a possible explanation follows:

(a) When the natural material is compacted either dynamically or statically below a moisture content of 10 percent and subsequently saturated; the term saturated being used in its colloquial sense, the flocculent or aggregated structure of the fines tends to persist.

(b) There is probably a tendency for the clay to disperse with time but it is believed this tendency is greatly augmented by mechanical disturbances of the structure brought about by changing stress

conditions within the soil mass. Therefore, if the material is compacted to a given density at a moisture content below 10 percent and then tested for permeability the resulting coefficent of permeability will, due to the persistance of the aggregated structure, be very much higher than if the specimen is brought to this density in the saturated state and the clay is dispersed in the process.

It is believed that this break-down of the aggregated clay structure also explains the fundamental difference in the shape of the permeability-density curves obtained in this investigation and those obtained by Burmister (18). In this investigation the effect on permeability of changes in density or void ratio during the early stages of densification are completely masked by incidental changes in structure. These did not occur in Burmister's tests because he placed and compacted the material in the dry state for each test. The permeability density curves established by tests number 5, 4, 3 and the initial points of 7, 9 and 13 more closely approximate the shape of Burmister's curves.

From a study of Plate XVIII it can be seen that there is no great difference in the initial permeability of tests numbers 7, 9, 11, 12 and 13, and the additives do not seem to have much effect until after the samples were subjected to mechanical distortion. Tests number 3 and 4 also illustrate this. It is concluded, therefore, that the main influence of the additives is simply to hold the clay fraction in an aggregated state during mechanical distortion of the material.

As indicated in the summary of results a limited number of moisture content determinations were made on the permeated material and from these data the final degree of saturation was computed. These data are not considered too reliable for reasons already mentioned but they do tend to indicate that complete saturation was not achieved. According to Lambe (17) complete saturation rarely is achieved in permeability tests. While the degree of saturation is known to influence the permeability (11) it is considered that in these tests the effects of the relatively small percentage of air in the voids would be minor compared to the effects attributed to changes in soil structure and density.

In summary the results showed that the permeability of Crawford pit material of given gradation may vary by a ratio of 100,000 and seemed to depend on the following variables:

(a) The density of the material.

(b) The method of preparing and compacting the specimen.

(c) The amount of permeation.

(d) Incidental structural changes that occur during permeation that seem in turn to depend on variations in (a), (b) and (c) above.

Other investigators (11), (17) and (18) have shown that the following variables also have a major influence on permeability:

(e) The degree of saturation.

(f) The percentage of material passing the number 200 sieve.

(g) The plasticity characteristics of the minus number 200 sieve fraction.

# CHAPTER XV

## CONCLUSIONS

On the strength of the test results obtained and the argument presented in explanation thereof the following conclusions may be drawn:

1. The permeability of the native Crawford and Winger pit materials investigated is an extremely variable and difficult quantity to measure and will depend on at least seven different variables each of which can exert a major influence thereon.

2. It is concluded therefore that considerable research remains to be done before the permeability test can be used in the routine selection and classification of sub marginal aggregates.

3. When the minus 3 inch Crawford pit material is mixed and compacted at moisture contents of less than 10.0 percent there appears an aggregated type of structure in the clayey fraction that is not completely broken down by mechanical distortion or the compaction process as long as the moisture content remains below 10.0 percent.

4. Mechanical distortion of the material in the saturated state causes a break down of the above structure, dispersion of the clay fraction, and a reduction of the permeability.

5. The addition of Portland cement or lime and fly ash in the concentrations tested had a minor influence on the permeability of the material in comparison to the influence of some of the other variables.

6. The main influence of the additives was to retard the break down of the aggregated structure in the clay fraction when the material was disturbed in the saturated condition.

7. The superior shearing strength characteristics of the treated material that have been observed by others (1) (2) can only be attributed in part to improved or increased permeability.

# CHAPTER XVI

## CONCLUDING DISCUSSION AND RECOMMENDATIONS FOR FUTURE RESEARCH

Before making any specific recommendations for future research it would be well to review very briefly and in general terms what has been accomplished to date because it is largely on these grounds that the recommendations are made.

Clark (1) and Millions (2) have shown that the addition of various small quantities of Portland cement or lime and fly ash to Crawford pit gravel resulted in an appreciable gain in shearing strength when tested in the 12 inch vacuum triaxial apparatus at moisture contents generally below 6 percent. However, Millions was able to show that when the moisture content was raised by as little as two or three percent both the treated and untreated material suffered a marked loss of strength. Even though both suffered a loss of strength the treated material was always superior to the untreated for any given moisture content.

These findings indicated that both additives could be effectively used to modify the material but two vitally important questions remained unanswered:

(1) Was the improvement in shearing strength permanent or would

it be destroyed by weathering; more specifically by cyclic freezing and thawing?

(2) Was the improvement in shearing strength of the treated material sufficient to ensure adequate performance under adverse drainage conditions?

Part "A" of this investigation was undertaken to obtain directly an answer to question number one. Part "B" was of a more academic nature the intention being to learn more about the behavior of the material and perhaps in a round about way get more information that would help to answer question number two.

With the reservations that will presently be stated, part "A" of this investigation might be considered successful in that it was shown that cyclic freezing actually benifited the material. Part "B" might be classed a failure and certainly was if evaluated from a purely practical point of view. However, lest erronious conclusions be drawn it must be stated that the question of durability has not yet been completely answered and cannot be until the answer to question number two is known.

As stated in Chapter VIII the strength gains observed by Clark and Millions are believed due mainly to material modification. If this strength gain is sufficient then the question of durability is answered. If this gain is not sufficient and higher additive concentrations are required in order to

achieve a soil cement type base then the influence of cyclic freezing and thawing might have a detrimental effect.

Now stability is not the only problem in connection with pavement foundations but it is certainly a major problem and the main one under consideration here. The main question remains therefore: What is the minimum acceptable saturated shearing strength and how can it be determined? Millions attempted to evaluate the material by the Kansas and Texas methods (19) but concluded as did Clark that there is no established and developed method of evaluating material of this nature.

Many organizations have been faced with similar problems in the past and took the logical step of developing a testing procedure that would give them the answers to the specific problems with which they were faced. Unfortunately most of the methods developed were highly empirical and this is precisely the reason why they cannot be used today to solve problems or predict the behavior of materials that are beyond their relatively narrow scopes.

It is considered therefore that the prime requirement at this time is the development of a suitable laboratory test that will permit a scientific evaluation of the shearing strength characteristics of the wide variety of materials that may with proper treatment be useable as flexible pavement sub base or base courses.

Clark and Millions had considerable success with the 12 inch vacuum triaxial test particularly on materials at a low moisture content. However, there is some doubt in the author's mind as to the reliability of the vacuum triaxial test on nearly saturated, highly impervious clay-aggregate mixtures of the type and grading used in this investigation. The reasoning behind this statement follows:

(a) In accordance with Boyle's Law, to reduce the pressure of a confined gas at constant temperature it is necessary to increase its volume. At relatively high degrees of saturation the air in the soil voids is completely surrounded by water (11) and to increase its volume a considerable quantity of water must be removed from the specimen. Now if the permeability of the material is very low and part "B" of this investigation indicates that it can be, this process may take considerable time.

(b) Even if sufficient time were allowed for static conditions to prevail, are we justified in assuming that no meniscus forces are acting and that the neutral stress is truly uniform throughout the specimen? If it can be shown that the neutral stress is in fact uniform will the material react to stress or more particularly changes in stress in the same way at this very much lower degree of saturation? According to Casegrande's Working Hypothesis (14) and the concepts of pore pressure parameters developed by Bishop and Henkel (20) it would not.

While these questions may be resolved, the vacuum triaxial test has one other major limitation and that is the relatively narrow range of lateral pressures that may be applied. The pressure cell type triaxial test would eliminate these problems and it is believed would be capable of producing stress conditions in all types of materials more closely approximating those that cause failure in the field.

Much remains to be learned about the true stress conditions in a pavement under a moving wheel load and a design engineer would have difficulty in applying triaxial test results directly to the problem of pavement design, however these problems may someday be resolved (21). Even if they are not resolved it should be possible to establish a workable correlation between triaxial test results and pavement thickness design as has been done by the Kansas State Highway Department (23).

Even if the correlation between the triaxial test results and field performance are empirical at least the laboratory test would be on a sound scientific foundation and any factors such as the addition of additives that would influence the stability or shearing strength in the field should be reflected in test results. Once the correlation is established the design engineer would be able to predict with more precision and confidence the benifits that may be derived from various types of treatment or processing. It may even be found that certain materials that will not meet current specifications could in fact be used for certain applications.

The preceeding treatise forms the main basis for the recommendations that will now be made.

1. Construct an experimental 18 inch pressure cell type triaxial apparatus and run a few preliminary tests mainly to solve some of the inevitable problems that will arise.

2. As a refinement to the basic apparatus add at some later date a pore pressure sensing system.

3. When a suitable test and test procedure has been developed carry out a field correlation study to determine minimum acceptable sub base aggregate shearing strength requirements.

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# APPENDIX A

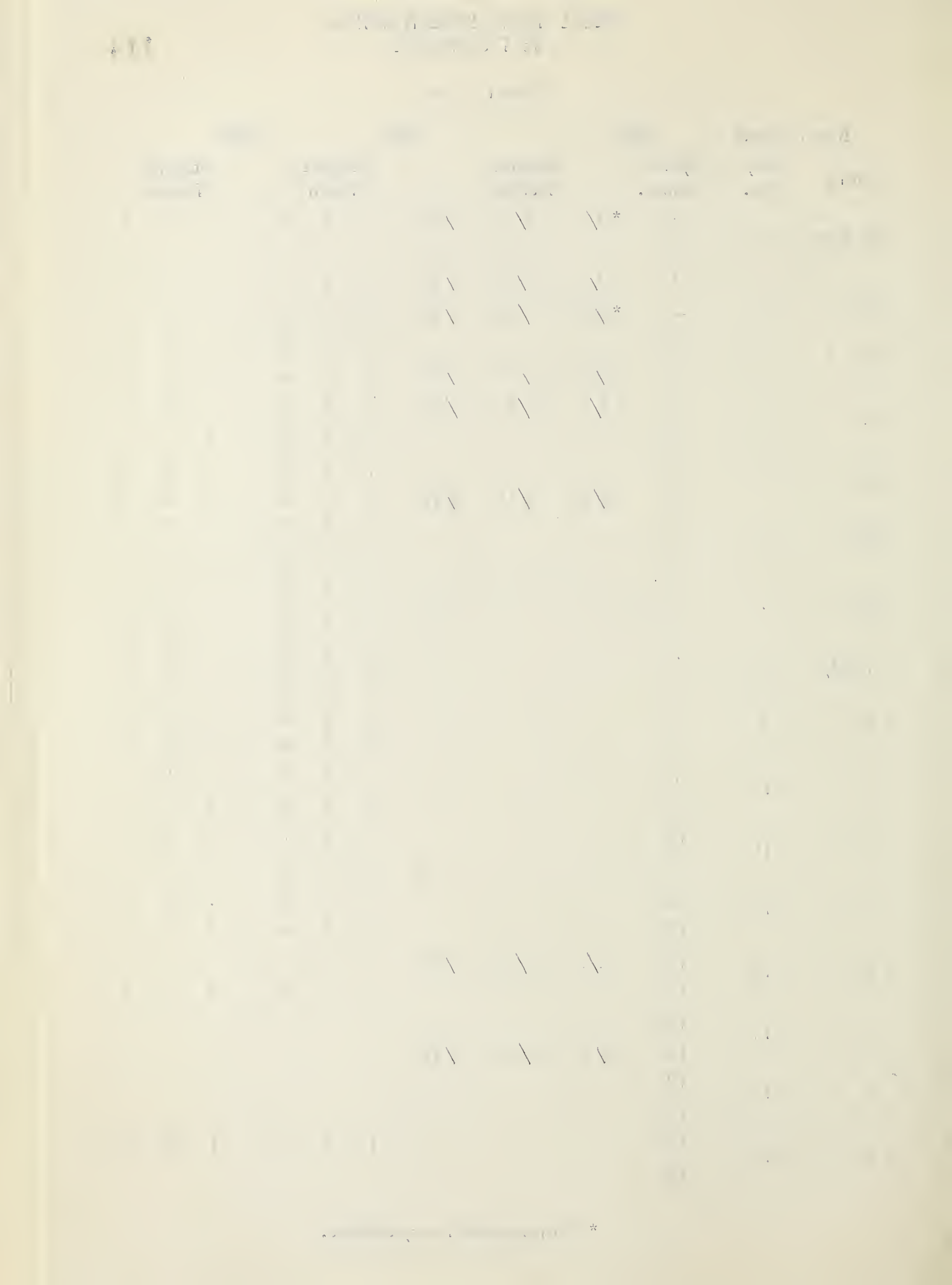
## Freeze Thaw Test Schedule

# FREEZE THAW INVESTIGATION
## TEST SCHEDULE

Sheet 1 of 4

| Time in Hours | | 1000 | | | | 1600 | | | | 2200 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Day No. | Cycles Compl. | Samples Tested | | | Samples Frozen | | | | Samples Thawed | | | |
| 24 June | 1 | -- | * 1/7 | 2/8 | 3/9 | 1 | 2 | 3 | | 1 | 2 | 3 | |
| | | -- | | | | | | | | | | | |
| 25 " | 2 | 1 | 1/7 | 2/8 | 3/9 | 1 | 2 | 3 | | 1 | 2 | 3 | |
| | | -- | *4/10 | 5/11 | 6/12 | 4 | 5 | 6 | | 4 | 5 | 6 | |
| 26 " | 3 | 2 | | | | 1 | 2 | 3 | | 1 | 2 | 3 | |
| | | 1 | 4/10 | 5/11 | 6/12 | 4 | 5 | 6 | | 4 | 5 | 6 | |
| 27 " | 4 | 3 | 1/7 | 2/8 | 3/9 | 1 | 2 | 3 | | 1 | 2 | 3 | |
| | | 2 | | | | 4 | 5 | 6 | | 4 | 5 | 6 | |
| 28 " | 5 | 4 | | | | 1 | 2 | 3 | | 1 | 2 | 3 | |
| | | 3 | 4/10 | 5/11 | 6/12 | 4 | 5 | 6 | | 4 | 5 | 6 | |
| 29 " | 6 | 5 | | | | 1 | 2 | 3 | | 1 | 2 | 3 | |
| | | 4 | | | | 4 | 5 | 6 | | 4 | 5 | 6 | |
| 30 " | 7 | 6 | | | | 1 | 2 | 3 | | 1 | 2 | 3 | |
| | | 5 | | | | 4 | 5 | 6 | | 4 | 5 | 6 | |
| 1 July | 8 | 7 | | | | 1 | 2 | 3 | | 1 | 2 | 3 | |
| | | 6 | | | | 4 | 5 | 6 | | 4 | 5 | 6 | |
| 2 " | 9 | 8 | | | | 1 | 2 | 3 | | 1 | 2 | 3 | |
| | | 7 | | | | 4 | 5 | 6 | | 4 | 5 | 6 | |
| 3 " | 10 | 9 | | | | 1 | 2 | 3 | | 1 | 2 | 3 | |
| | | 8 | | | | 4 | 5 | 6 | | 4 | 5 | 6 | |
| 4 " | 11 | 10 | | | | 1 | 2 | 3 | | 1 | 2 | 3 | |
| | | 9 | | | | 4 | 5 | 6 | | 4 | 5 | 6 | |
| 5 " | 12 | 11 | | | | 1 | 2 | 3 | | 1 | 2 | 3 | |
| | | 10 | | | | 4 | 5 | 6 | | 4 | 5 | 6 | |
| 6 " | 13 | 12 | 1/7 | 2/8 | 3/9 | | | | | | | | |
| | | 11 | | | | 4 | 5 | 6 | | 4 | 5 | 6 | |
| 7 " | 14 | 12 | | | | | | | | | | | |
| | | 12 | 4/10 | 5/11 | 6/12 | | | | | | | | |
| 8 " | 15 | 12 | | | | | | | | | | | |
| | | 12 | | | | | | | | | | | |
| 9 " | 16 | 12 | | | | 1 | 2 | 3 | | 1 | 2 | 3 | |
| | | 12 | | | | | | | | | | | |

* Water added to dry samples.



# FREEZE THAW INVESTIGATION
## TEST SCHEDULE

Sheet 2 of 4

| Time in Hours | | 1000 | | | | 1600 | | | 2200 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Day No. | Cycle Compl. | Samples Tested | | | Samples Frozen | | | Samples Thawed | | |
| 10 July | 17 | 13 | | | | 1 | 2 | 3 | 1 | 2 | 3 |
| | | 12 | | | | 4 | 5 | 6 | 4 | 5 | 6 |
| 11 " | 18 | 14 | | | | 1 | 2 | 3 | 1 | 2 | 3 |
| | | 13 | | | | 4 | 5 | 6 | 4 | 5 | 6 |
| 12 " | 19 | 15 | | | | 1 | 2 | 3 | 1 | 2 | 3 |
| | | | | | | 4 | 5 | 6 | 4 | 5 | 6 |
| 13 " | 20 | 16 | | | | 1 | 2 | 3 | 1 | 2 | 3 |
| | | | | | | 4 | 5 | 6 | 4 | 5 | 6 |
| 14 " | 21 | 17 | | | | 1 | 2 | 3 | 1 | 2 | 3 |
| | | | | | | 4 | 5 | 6 | 4 | 5 | 6 |
| 15 " | 22 | 18 | | | | 1 | 2 | 3 | 1 | 2 | 3 |
| | | | | | | 4 | 5 | 6 | 4 | 5 | 6 |
| 16 " | 23 | 19 | | | | 1 | 2 | 3 | 1 | 2 | 3 |
| | | | | | | 4 | 5 | 6 | 4 | 5 | 6 |
| 17 " | 24 | 20 | | | | 1 | 2 | 3 | 1 | 2 | 3 |
| | | | | | | 4 | 5 | 6 | 4 | 5 | 6 |
| 18 " | 25 | 21 | | | | 1 | 2 | 3 | 1 | 2 | 3 |
| | | | | | | 4 | 5 | 6 | 4 | 5 | 6 |
| 19 " | 26 | 22 | | | | 1 | 2 | 3 | 1 | 2 | 3 |
| | | | | | | 4 | 5 | 6 | 4 | 5 | 6 |
| 20 " | 27 | 23 | | | | 1 | 2 | 3 | 1 | 2 | 3 |
| | | | | | | 4 | 5 | 6 | 4 | 5 | 6 |
| 21 " | 28 | 24 | | | | 1 | 2 | 3 | 1 | 2 | 3 |
| | | | | | | 4 | 5 | 6 | 4 | 5 | 6 |
| 22 " | 29 | 25 | 1/7 | 2/8 | 3/9 | 1 | 2 | 3 | 1 | 2 | 3 |
| | | | | | | 4 | 5 | 6 | 4 | 5 | 6 |
| 23 " | 30 | 26 | | | | 1 | 2 | 3 | 1 | 2 | 3 |
| | | 25 | 4/10 | 5/11 | 6/12 | 4 | 5 | 6 | 4 | 5 | 6 |
| 24 " | 31 | 27 | | | | 1 | 2 | 3 | 1 | 2 | 3 |
| | | | | | | 4 | 5 | 6 | 4 | 5 | 6 |
| 25 " | 32 | | | | | 1 | 2 | 3 | 1 | 2 | 3 |
| | | | | | | 4 | 5 | 6 | 4 | 5 | 6 |

# FREEZE THAW INVESTIGATION
## TEST SCHEDULE

Sheet 3 of 4

| Time in Hours | | 1000 | | 1600 | | 2200 | |
|---|---|---|---|---|---|---|---|
| Date | Day No. | Cycles Compl. | Samples Tested | Samples Frozen | | Samples Thawed | |
| 26 July | 33 | 29 | | 1 2 3<br>4 5 6 | | 1 2 3<br>4 5 6 | |
| 27 " | 34 | 30 | | 1 2 3<br>4 5 6 | | 1 2 3<br>4 5 6 | |
| 28 " | 35 | 31 | | 1 2 3<br>4 5 6 | | 1 2 3<br>4 5 6 | |
| 29 " | 36 | 32 | | 1 2 3<br>4 5 6 | | 1 2 3<br>4 5 6 | |
| 30 " | 37 | 33 | | 1 2 3<br>4 5 6 | | 1 2 3<br>4 5 6 | |
| 31 " | 38 | 34 | | 1 2 3<br>4 5 6 | | 1 2 3<br>4 5 6 | |
| 1 Aug. | 39 | 35 | | No freeze cycle | | | |
| 2 ," | 40 | 35 | | 1 2 3<br>4 5 6 | | 1 2 3<br>4 5 6 | |
| 3 " | 41 | 36 | | 1 2 3<br>4 5 6 | | 1 2 3<br>4 5 6 | |
| 4 " | 42 | 37 | | 1 2 3<br>4 5 6 | | 1 2 3<br>4 5 6 | |
| 5 " | 43 | 38 | | 1 2 3<br>4 5 6 | | 1 2 3<br>4 5 6 | |
| 6 " | 44 | 39 | | 1 2 3<br>4 5 6 | | 1 2 3<br>4 5 6 | |
| 7 " | 45 | 40 | | 1 2 3<br>4 5 6 | | 1 2 3<br>4 5 6 | |
| 8 " | 46 | 41 | | 1 2 3<br>4 5 6 | | 1 2 3<br>4 5 6 | |
| 9 " | 47 | 42 | | 1 2 3<br>4 5 6 | | 1 2 3<br>4 5 6 | |
| 10 " | 48 | 43 | | 1 2 3<br>4 5 6 | | 1 2 3<br>4 5 6 | |

# FREEZE THAW INVESTIGATION
## TEST SCHEDULE

Sheet 4 of 4

| Time in Hours | | 1000 | | | 1600 | | | 2200 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Day No. | Cycles Compl. | Samples Tested | | Samples Frozen | | | Samples Thawed | | |
| 11 Aug. | 49 | 44 | | | 1 | 2 | 3 | 1 | 2 | 3 |
| | | | | | 4 | 5 | 6 | 4 | 5 | 6 |
| 12 " | 50 | 45 | | | 1 | 2 | 3 | 1 | 2 | 3 |
| | | | | | 4 | 5 | 6 | 4 | 5 | 6 |
| 13 " | 51 | 46 | | | 1 | 2 | 3 | 1 | 2 | 3 |
| | | | | | 4 | 5 | 6 | 4 | 5 | 6 |
| 14 " | 52 | 47 | | | 1 | 2 | 3 | 1 | 2 | 3 |
| | | 46 | | | 4 | 5 | 6 | 4 | 5 | 6 |
| 15 " | 53 | 48 | 1/7 | 2/8 | | | | | | |
| | | 47 | | | 4 | 5 | 6 | 4 | 5 | 6 |
| 16 " | 54 | 48 | 3/9 | | | | | | | |
| | | 48 | 4/10 | | | | | | | |
| 17 " | 55 | 48 | 5/11 | 6/12 | | | | | | |

# APPENDIX B

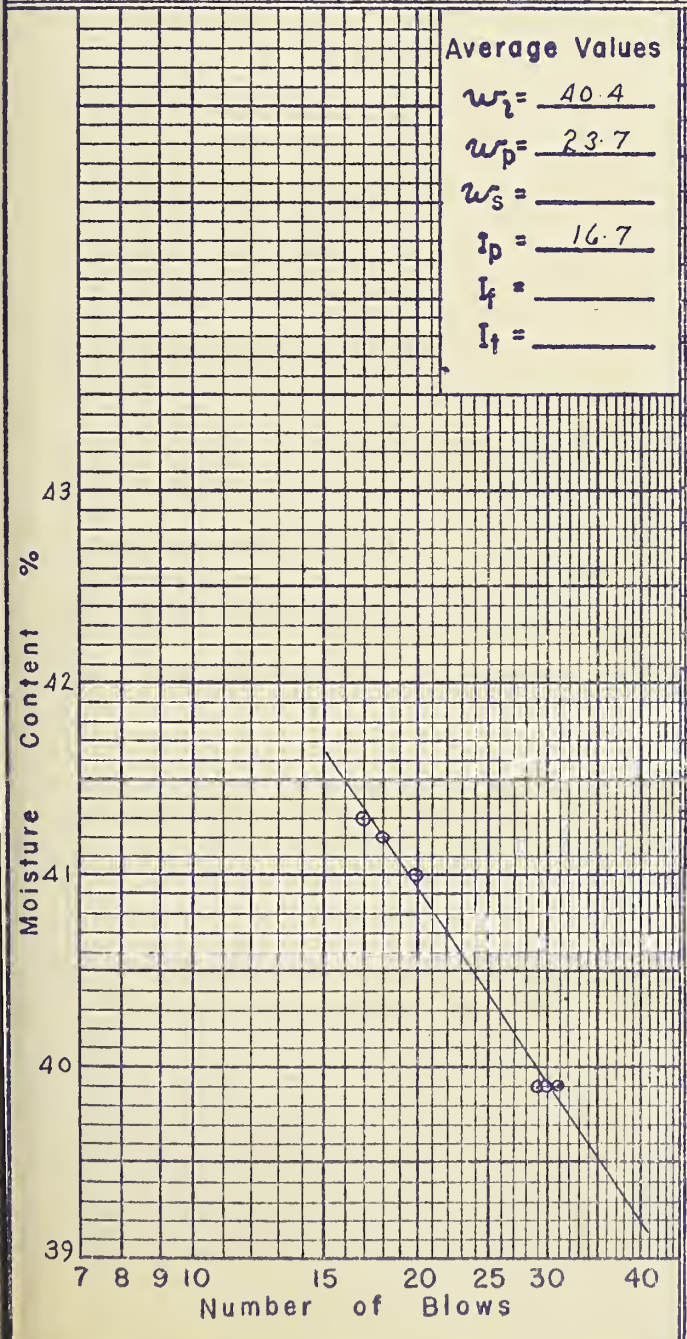
## Detailed Test Data for Part "A"

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE - #40 Control Sample
LOCATION No Additive
HOLE DEPTH
TECHNICIAN T.S.M. DATE 25-6-59

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 17 | 18 | 20 | 31 | 30 | 29 |
| Container No. | V73 | V88 | V84 | V80 | V72 | V83 |
| Wt. Sample Wet + Tare | 96.48 | 112.96 | 106.72 | 96.78 | 96.21 | 98.40 |
| Wt. Sample Dry + Tare | 87.68 | 102.60 | 97.60 | 89.71 | 88.73 | 90.63 |
| Wt. Water | 8.80 | 10.36 | 9.12 | 7.07 | 7.48 | 7.77 |
| Tare Container | 66.28 | 77.43 | 75.38 | 72.00 | 70.00 | 71.16 |
| Wt. of Dry Soil | 21.40 | 25.17 | 22.22 | 17.71 | 18.73 | 19.47 |
| Moisture Content $w$% | 41.3 | 41.2 | 41.0 | 39.9 | 39.9 | 39.9 |




**Average Values**

$w_l$ = 40.4
$w_p$ = 23.7
$w_s$ = ____
$I_p$ = 16.7
$I_f$ = ____
$I_t$ = ____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AH | AM | BT |
| Wt. Sample Wet+Tare | 62.122 | 62.297 | 62.455 |
| Wt. Sample Dry+Tare | 60.188 | 60.560 | 60.645 |
| Wt. Water | 1.934 | 1.737 | 1.810 |
| Tare Container | 52.057 | 53.162 | 53.062 |
| Wt. of Dry Soil | 8.131 | 7.398 | 7.583 |
| Moisture Content % | 23.8 | 23.6 | 23.9 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

Remarks: Sample soaked 24 hrs.

UNIVERSITY of ALBERTA
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SOIL MECHANICS LABORATORY

# ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest. |
| SITE | Crawford Pit |
| SAMPLE | # 1 |
| LOCATION | |
| ~~HOLE~~ | Cycle # 1 DEPTH |
| TECHNICIAN | T.S.W. DATE 25-6-59 |

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 20 | 21 | 22 | 28 | 29 | 35 |
| Container No. | V62 | V61 | V78 | V77 | V74 | V85 |
| Wt. Sample Wet + Tare | 98.84 | 105.88 | 117.70 | 95.43 | 96.48 | 109.73 |
| Wt. Sample Dry + Tare | 89.42 | 97.80 | 108.00 | 89.76 | 89.50 | 101.68 |
| Wt. Water | 9.42 | 8.08 | 9.70 | 5.67 | 6.98 | 8.05 |
| Tare Container | 65.05 | 76.70 | 82.78 | 74.80 | 71.11 | 80.42 |
| Wt. of Dry Soil | 24.37 | 21.10 | 25.22 | 14.96 | 18.39 | 21.26 |
| Moisture Content $w$% | 38.7 | 38.3 | 38.4 | 37.9 | 38.0 | 37.8 |

Average Values

$w_l$ = 38.2

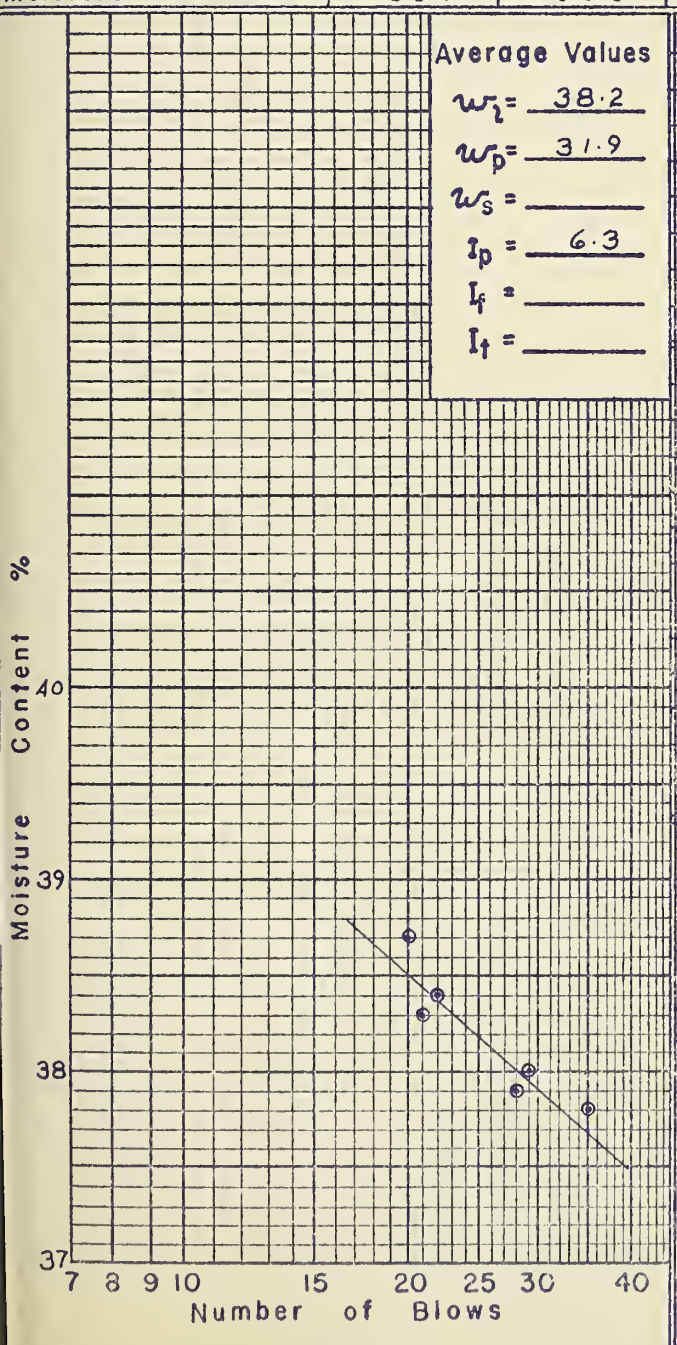
$w_p$ = 31.9

$w_s$ = _____

$I_p$ = 6.3

$I_f$ = _____

$I_t$ = _____




## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BW | BR | AV |
| Wt. Sample Wet+Tare | 65.823 | 60.936 | 65.064 |
| Wt. Sample Dry+Tare | 63.079 | 58.708 | 62.563 |
| Wt. Water | 2.744 | 2.228 | 2.501 |
| Tare Container | 54.734 | 51.756 | 54.431 |
| Wt. of Dry Soil | 8.345 | 6.952 | 8.132 |
| Moisture Content % | 32.9 | 32.1 | 30.8 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

Remarks: _____

# UNIVERSITY of ALBERTA
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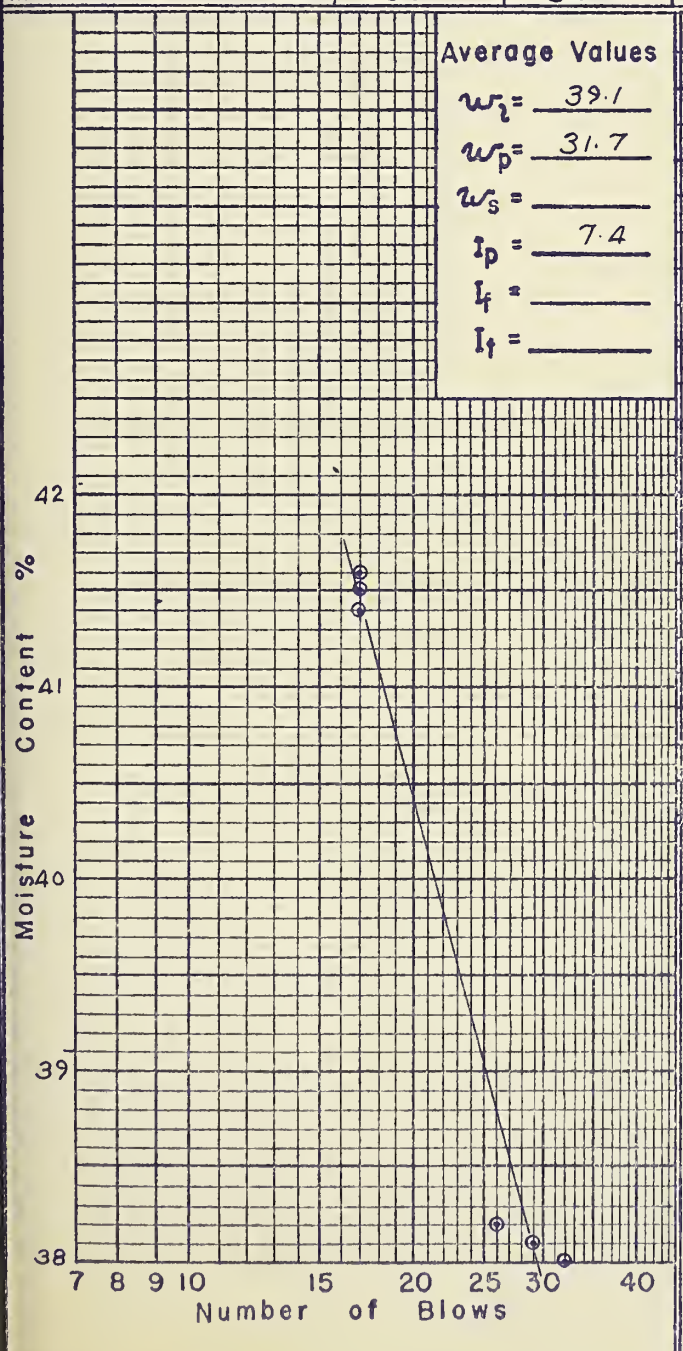
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest
SITE Crawford Pit
SAMPLE # 1
LOCATION
~~HOLE~~ Cycle # 3 DEPTH Day # 4
TECHNICIAN TSN DATE 27-6-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 29 | 26 | 32 | 17 | 17 | 17 |
| Container No. | V8 | V3 | V7 | V6 | V9 | V66 |
| Wt. Sample Wet + Tare | 82.52 | 87.17 | 91.79 | 94.90 | 103.73 | 96.47 |
| Wt. Sample Dry + Tare | 77.10 | 80.80 | 85.56 | 89.58 | 96.64 | 87.62 |
| Wt. Water | 5.41 | 6.37 | 6.23 | 5.32 | 7.09 | 8.85 |
| Tare Container | 62.91 | 64.10 | 69.16 | 76.78 | 79.58 | 66.43 |
| Wt. of Dry Soil | 14.20 | 16.70 | 16.40 | 12.80 | 17.06 | 21.19 |
| Moisture Content w% | 38.1 | 38.2 | 38.0 | 41.6 | 41.5 | 41.4 |




**Average Values**

$w_l$ = 39.1
$w_p$ = 31.7
$w_s$ = ____
$I_p$ = 7.4
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | RC | RH | RE |
| Wt. Sample Wet+Tare | 63.342 | 58.983 | 58.680 |
| Wt. Sample Dry+Tare | 60.975 | 57.329 | 57.344 |
| Wt. Water | 2.367 | 1.654 | 1.336 |
| Tare Container | 53.693 | 52.057 | 53.087 |
| Wt. of Dry Soil | 7.336 | 5.272 | 4.257 |
| Moisture Content % | 32.3 | 31.4 | 31.3 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content w% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

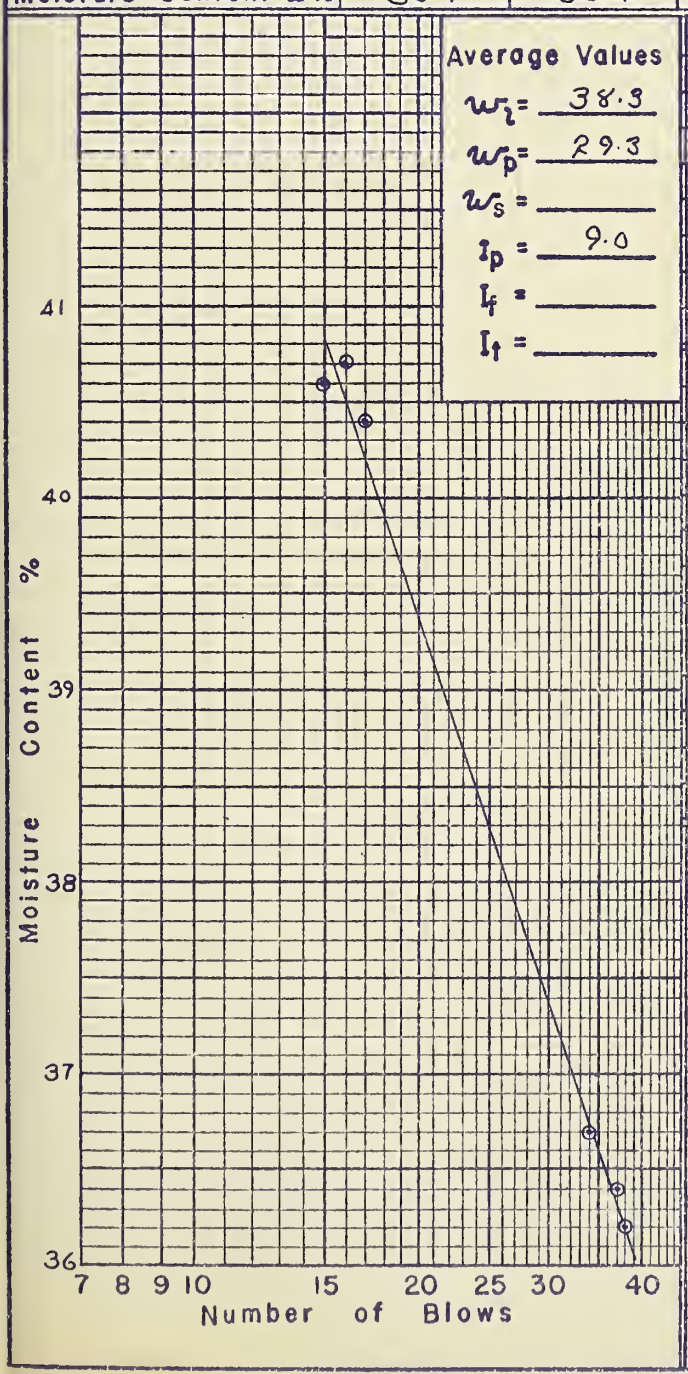
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 1
LOCATION
~~HOLE~~ Cycle # 12 ~~DEPTH~~ Day # 13
TECHNICIAN TSW DATE 6-7-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 34 | 37 | 38 | 16 | 15 | 17 |
| Container No. | V78 | V67 | V42 | V59 | V66 | V83 |
| Wt. Sample Wet + Tare | 104.29 | 87.03 | 86.87 | 88.24 | 88.04 | 98.52 |
| Wt. Sample Dry + Tare | 98.51 | 82.20 | 81.69 | 82.49 | 81.80 | 90.65 |
| Wt. Water | 5.78 | 4.83 | 5.18 | 5.75 | 6.24 | 7.87 |
| Tare Container | 82.78 | 68.91 | 67.38 | 68.38 | 66.43 | 71.16 |
| Wt. of Dry Soil | 15.73 | 13.29 | 14.31 | 14.11 | 15.37 | 19.49 |
| Moisture Content $w$% | 36.7 | 36.4 | 36.2 | 40.7 | 40.6 | 40.4 |




**Average Values**

$w_l$ = 38.3
$w_p$ = 29.3
$w_s$ = ____
$I_p$ = 9.0
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BW | AP | BA |
| Wt. Sample Wet+Tare | 67.312 | 60.171 | 60.119 |
| Wt. Sample Dry+Tare | 64.431 | 58.653 | 58.236 |
| Wt. Water | 2.881 | 1.518 | 1.883 |
| Tare Container | 54.734 | 53.395 | 51.756 |
| Wt. of Dry Soil | 9.697 | 5.258 | 6.480 |
| Moisture Content % | 29.8 | 28.9 | 29.1 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

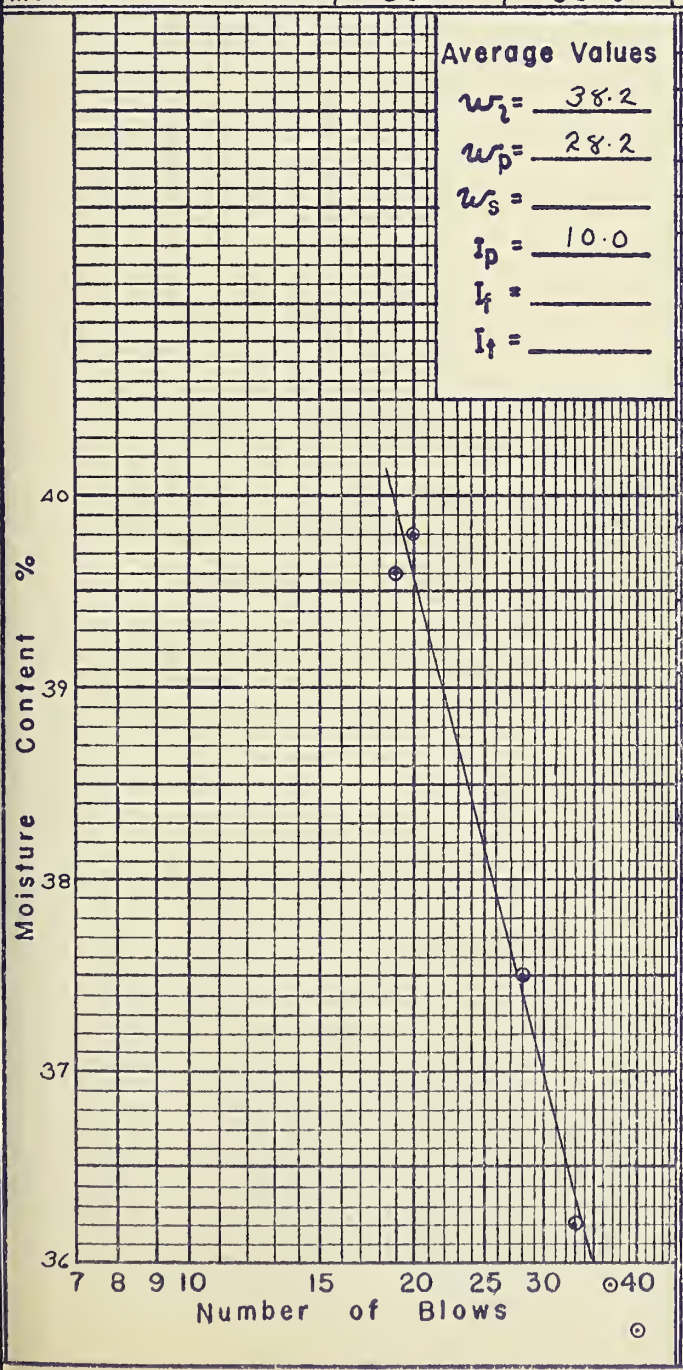
Remarks: _____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze-Thaw Invest.
SITE Crawford Pit
SAMPLE # 1
LOCATION
~~HOLE~~ Cycle # 25 ~~DEPTH~~ Day 29
TECHNICIAN Tsui DATE 22-7-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 33 | 37 | 28 | 20 | 19 | 40 |
| Container No. | V78 | VA7 | V77 | V3 | V62 | V52 |
| Wt. Sample Wet + Tare | 105.35 | 86.30 | 99.38 | 90.55 | 89.14 | 99.62 |
| Wt. Sample Dry + Tare | 99.35 | 80.42 | 92.68 | 83.02 | 80.32 | 93.10 |
| Wt. Water | 6.00 | 5.88 | 6.70 | 7.53 | 6.82 | 6.52 |
| Tare Container | 82.78 | 64.00 | 74.80 | 64.10 | 65.05 | 74.82 |
| Wt. of Dry Soil | 16.57 | 16.42 | 17.88 | 18.92 | 17.27 | 18.28 |
| Moisture Content $w$% | 36.2 | 35.8 | 37.5 | 39.8 | 39.6 | 35.6 |




**Average Values**

$w_l$ = 38.2
$w_p$ = 28.2
$w_s$ = ____
$I_p$ = 10.0
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AD | RH | AC |
| Wt. Sample Wet+Tare | 57.480 | 56.733 | 58.525 |
| Wt. Sample Dry+Tare | 56.353 | 55.702 | 57.447 |
| Wt. Water | 1.127 | 1.031 | 1.078 |
| Tare Container | 52.326 | 52.057 | 53.639 |
| Wt. of Dry Soil | 4.027 | 3.645 | 3.808 |
| Moisture Content % | 28.0 | 28.3 | 28.3 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: F.T. Sample has darker color, more granular friable texture. Becomes more plastic upon mixing

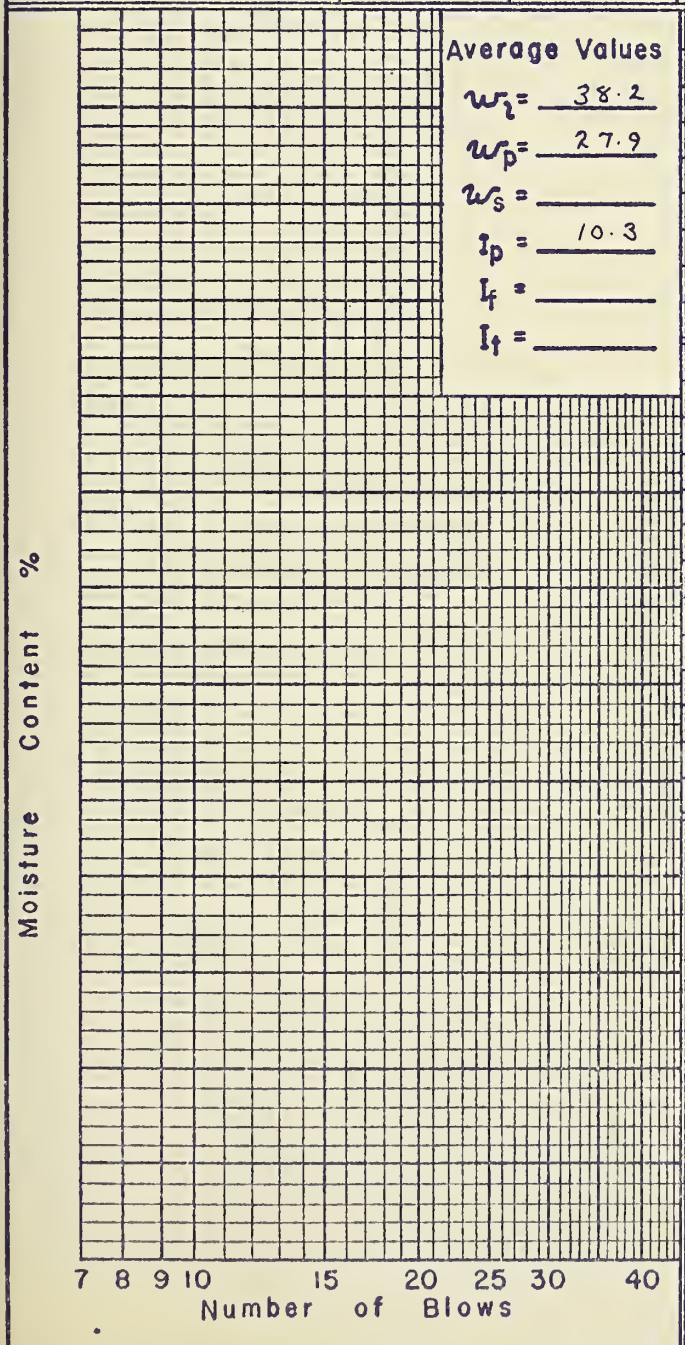
Remarks: These characteristics more pronounced with increasing additive content

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE #1
LOCATION
HOLE Cycle # 26 DEPTH
TECHNICIAN T.S.N. DATE 23-7-59

### Liquid Limit

| | | | | | | |
|---|---|---|---|---|---|---|
| Trial No. | | | | | | |
| No. of Blows | | | | | | |
| Container No. | | | | | | |
| Wt. Sample Wet + Tare | | | | | | |
| Wt. Sample Dry + Tare | | | | | | |
| Wt. Water | | | | | | |
| Tare Container | | | | | | |
| Wt. of Dry Soil | | | | | | |
| Moisture Content $w$% | | | | | | |




Average Values
$w_l$ = 38.2
$w_p$ = 27.9
$w_s$ = ____
$I_p$ = 10.3
$I_f$ = ____
$I_t$ = ____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | RV | RT | BE |
| Wt. Sample Wet+Tare | 60.526 | 58.478 | 58.159 |
| Wt. Sample Dry+Tare | 59.184 | 57.440 | 57.334 |
| Wt. Water | 1.342 | 1.038 | 0.825 |
| Tare Container | 54.431 | 53.715 | 54.381 |
| Wt. of Dry Soil | 4.753 | 3.725 | 2.953 |
| Moisture Content % | 28.2 | 27.8 | 27.9 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

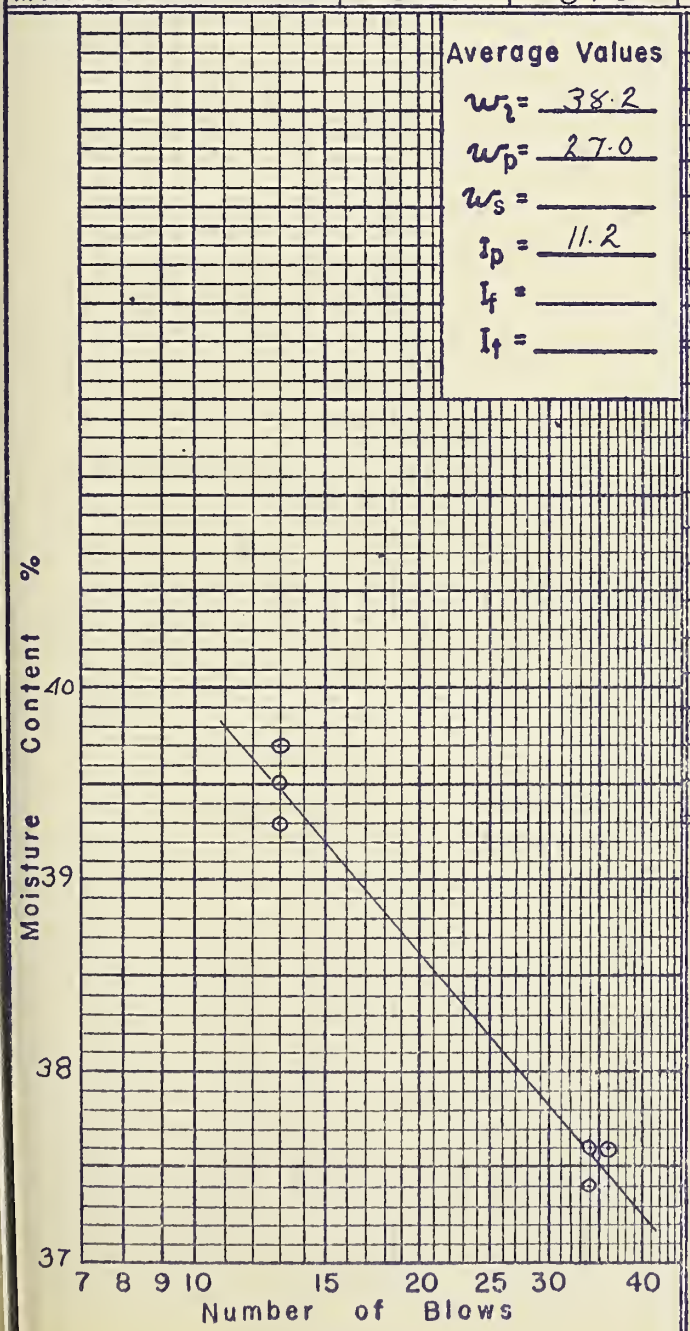
Remarks: ____
Check plastic limit Test.

# UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 1
LOCATION
~~HOLE~~ Cycle "A8 DEPTH
TECHNICIAN T.S.J. DATE 15-8-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 13 | 13 | 13 | 36 | 34 | 34 |
| Container No. | V83 | V71 | V46 | V88 | V58 | V63 |
| Wt. Sample Wet + Tare | 88.90 | 94.10 | 105.37 | 94.00 | 88.34 | 88.12 |
| Wt. Sample Dry + Tare | 83.89 | 88.58 | 99.21 | 89.48 | 83.23 | 82.60 |
| Wt. Water | 5.01 | 5.52 | 6.16 | 4.52 | 5.11 | 5.52 |
| Tare Container | 71.16 | 74.63 | 83.71 | 77.43 | 69.63 | 67.80 |
| Wt. of Dry Soil | 12.73 | 13.95 | 15.50 | 12.05 | 13.60. | 14.80 |
| Moisture Content $w$% | 39.3 | 39.5 | 39.7 | 37.6 | 37.6 | 37.4 |




**Average Values**

$w_l$ = 38.2
$w_p$ = 27.0
$w_s$ = ____
$I_p$ = 11.2
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AH | BE | AE |
| Wt. Sample Wet+Tare | 60.443 | 61.440 | 59.398 |
| Wt. Sample Dry+Tare | 58.630 | 59.947 | 58.077 |
| Wt. Water | 1.813 | 1.493 | 1.321 |
| Tare Container | 52.057 | 54.381 | 53.087 |
| Wt. of Dry Soil | 6.573 | 5.566 | 4.990 |
| Moisture Content % | 27.6 | 26.9 | 26.5 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

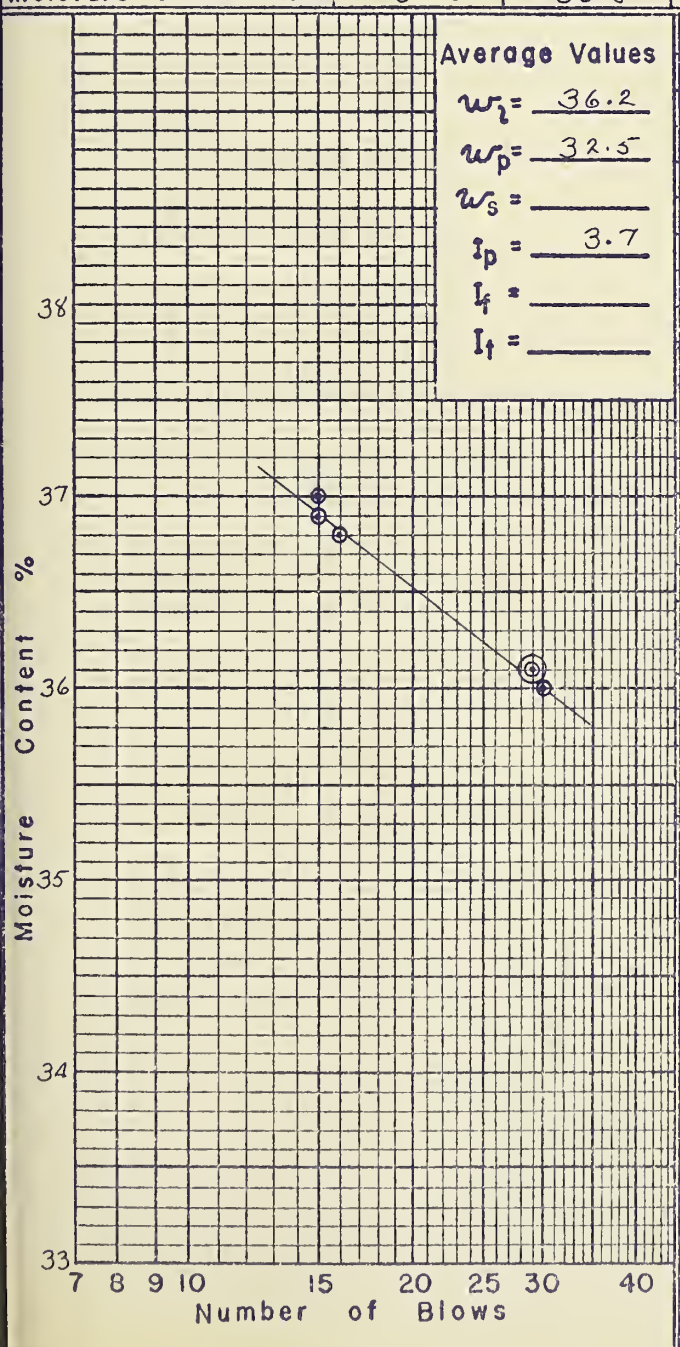
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze Thaw Investigation
SITE Crawford Pit
SAMPLE # 2
LOCATION
~~HOLE~~ Cycle # 1 ~~DEPTH~~ Day # 2
TECHNICIAN D.S. DATE 25-6-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 15 | 16 | 15 | 29 | 29 | 30 |
| Container No. | V 50 | V 51 | V 52 | V 57 | V 58 | V 59 |
| Wt. Sample Wet + Tare | 112.45 | 91.13 | 95.54 | 87.22 | 85.41 | 85.39 |
| Wt. Sample Dry + Tare | 104.10 | 84.41 | 89.95 | 82.89 | 81.23 | 80.88 |
| Wt. Water | 8.35 | 6.72 | 5.59 | 4.33 | 4.18 | 4.51 |
| Tare Container | 81.54 | 66.13 | 74.82 | 70.91 | 69.63 | 68.38 |
| Wt. of Dry Soil | 22.56 | 18.28 | 15.13 | 11.98 | 11.60 | 12.50 |
| Moisture Content $w$% | 37.0 | 36.8 | 36.9 | 36.1 | 36.1 | 36.0 |




Average Values
$w_l$ = 36.2
$w_p$ = 32.5
$w_s$ = ____
$I_p$ = 3.7
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | 28 | BE | BK |
| Wt. Sample Wet+Tare | 43.275 | 61.151 | 63.246 |
| Wt. Sample Dry+Tare | 41.502 | 59.501 | 60.724 |
| Wt. Water | 1.773 | 1.650 | 2.522 |
| Tare Container | 36.030 | 54.381 | 53.262 |
| Wt. of Dry Soil | 5.472 | 5.120 | 7.462 |
| Moisture Content % | 32.4 | 32.2 | 33.8 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

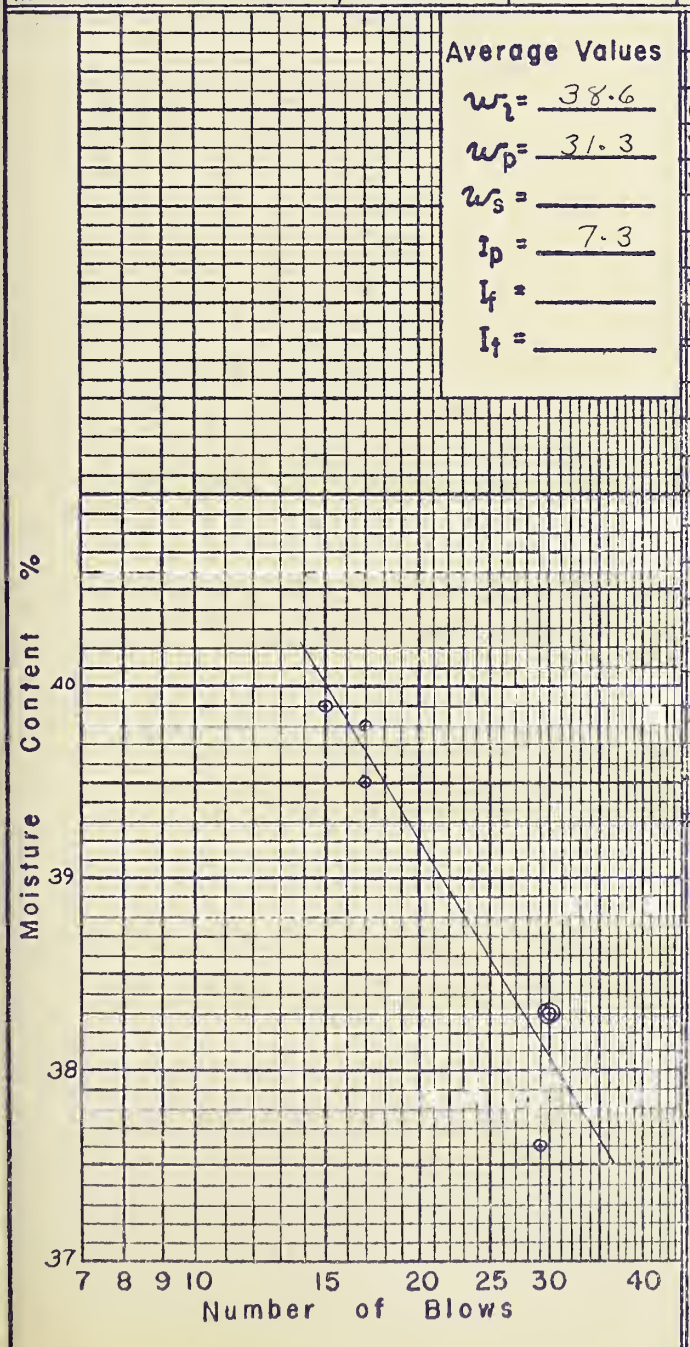
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 2
LOCATION
HOLE Cycle #3 DEPTH Day 4
TECHNICIAN DS DATE 27-6-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 15 | 17 | 17 | 29 | 30 | 30 |
| Container No. | V85 | V73 | V81 | V84 | V50 | V80 |
| Wt. Sample Wet + Tare | 93.89 | 80.78 | 87.92 | 92.80 | 98.25 | 88.61 |
| Wt. Sample Dry + Tare | 90.05 | 76.66 | 84.60 | 88.04 | 93.62 | 84.01 |
| Wt. Water | 3.84 | 4.12 | 3.32 | 4.76 | 4.63 | 4.60 |
| Tare Container | 80.42 | 66.28 | 76.19 | 75.38 | 81.54 | 72.00 |
| Wt. of Dry Soil | 9.63 | 10.38 | 8.41 | 12.66 | 12.08 | 12.01 |
| Moisture Content $w$% | 39.9 | 39.8 | 39.5 | 37.6 | 38.3 | 38.3 |




**Average Values**

$w_l$ = 38.6
$w_p$ = 31.3
$w_s$ = ____
$I_p$ = 7.3
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | 22 | B1 | BL |
| Wt. Sample Wet+Tare | 43.225 | 63.485 | 65.605 |
| Wt. Sample Dry+Tare | 41.432 | 61.443 | 63.033 |
| Wt. Water | 1.793 | 2.042 | 2.572 |
| Tare Container | 35.747 | 54.942 | 54.741 |
| Wt. of Dry Soil | 5.685 | 6.501 | 8.292 |
| Moisture Content % | 31.6 | 31.4 | 31.0 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

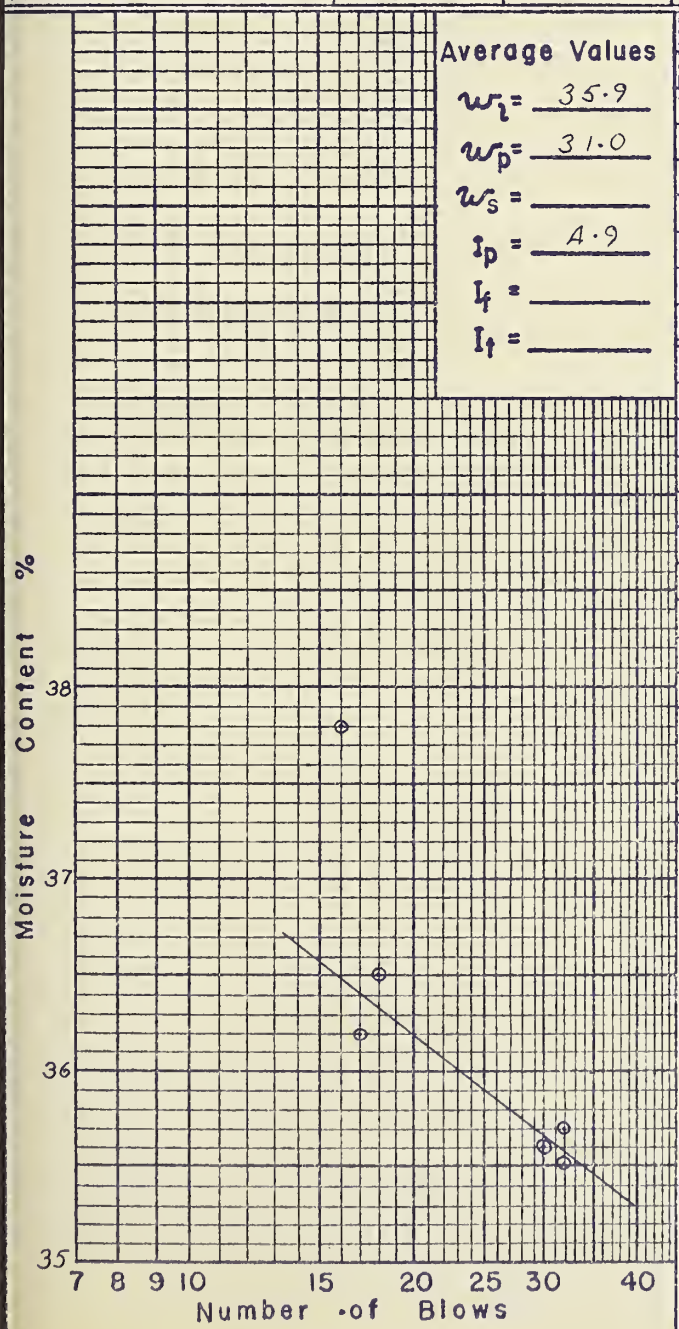
Remarks: Sample glistened with with surface moisture upon removal from tin. Water added and sample vigorously worked to get consistant Blow count

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE #2
LOCATION
~~HOLE~~ Cycle #12 ~~DEPTH~~ Day 13
TECHNICIAN D.S. DATE 6-7-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 16 | 17 | 18 | 30 | 32 | 32 |
| Container No. | V10 | V65 | V68 | V45 | V69 | V50 |
| Wt. Sample Wet + Tare | 82.37 | 81.20 | 100.86 | 84.88 | 86.88 | 97.40 |
| Wt. Sample Dry + Tare | 78.82 | 77.66 | 97.20 | 80.89 | 82.29 | 93.24 |
| Wt. Water | 3.55 | 3.54 | 3.66 | 3.99 | 4.59 | 4.16 |
| Tare Container | 69.43 | 67.88 | 87.13 | 69.69 | 69.41 | 81.54 |
| Wt. of Dry Soil | 9.39 | 9.78 | 10.07 | 11.20 | 12.88 | 11.70 |
| Moisture Content $w$% | 37.8 | 36.2 | 36.5 | 35.6 | 35.7 | 35.5 |




**Average Values**

$w_l$ = 35.9
$w_p$ = 31.0
$w_s$ = ____
$I_p$ = 4.9
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AM | BL | AS |
| Wt. Sample Wet+Tare | 69.463 | 66.713 | 71.232 |
| Wt. Sample Dry+Tare | 65.754 | 63.959 | 67.377 |
| Wt. Water | 3.709 | 2.754 | 3.855 |
| Tare Container | 53.162 | 54.741 | 54.249 |
| Wt. of Dry Soil | 11.592 | 9.218 | 13.128 |
| Moisture Content % | 32.1 | 29.9 | 29.4 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

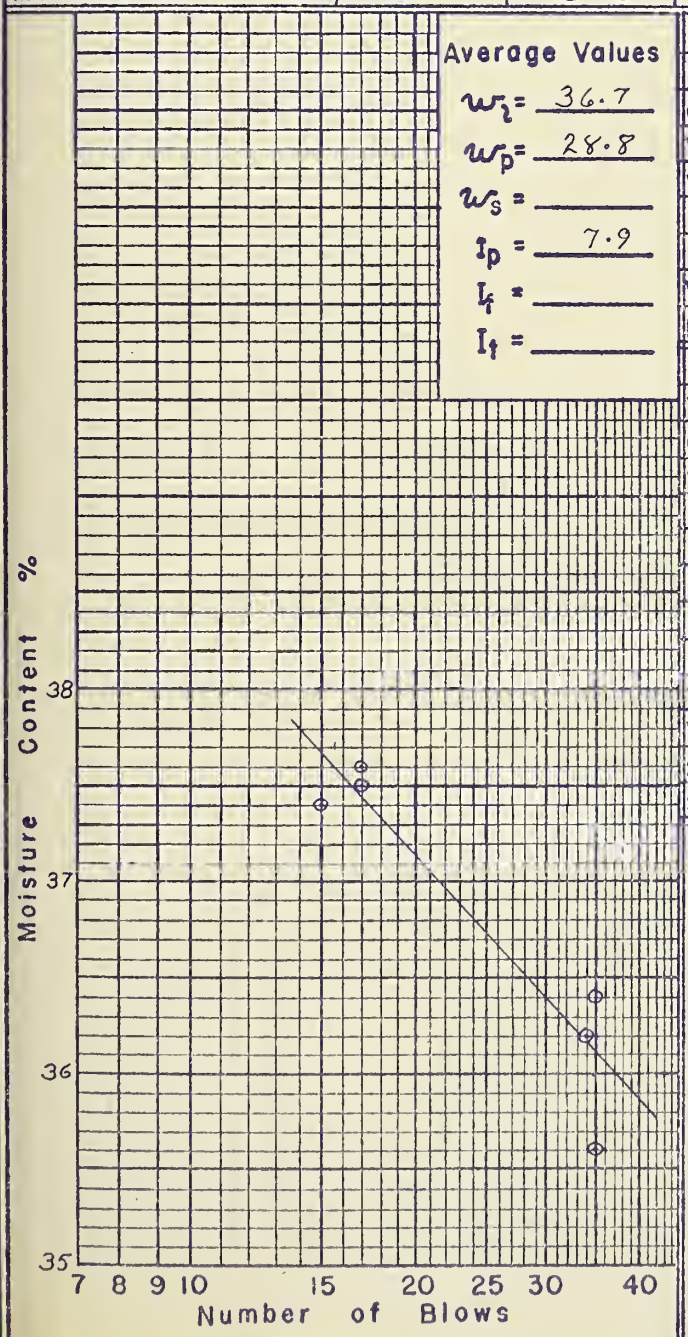
Remarks: Dashed Line is correction based on average slope of other test results.

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crowford Pit
SAMPLE # 2
LOCATION
~~HOLE~~ Cycle # 25 ~~DEPTH~~ Day 29
TECHNICIAN DS. DATE 22-7-59

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 15 | 17 | 17 | 35 | 35 | 34 |
| Container No. | V6 | V65 | V67 | V73 | V66 | V42 |
| Wt. Sample Wet + Tare | 99.41 | 90.50 | 97.58 | 85.35 | 87.09 | 89.25 |
| Wt. Sample Dry + Tare | 93.23 | 84.32 | 89.76 | 80.26 | 81.55 | 83.43 |
| Wt. Water | 6.18 | 6.18 | 7.82 | 5.09 | 5.54 | 5.82 |
| Tare Container | 76.78 | 67.88 | 68.91 | 66.28 | 66.43 | 67.38 |
| Wt. of Dry Soil | 16.55 | 16.44 | 20.85 | 13.98 | 15.12 | 16.05 |
| Moisture Content $w$% | 37.4 | 37.6 | 37.5 | 36.4 | 35.6 | 36.2 |




**Average Values**

$w_l$ = 36.7
$w_p$ = 28.8
$w_s$ = ____
$I_p$ = 7.9
$I_f$ = ____
$I_t$ = ____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | 22 | 28 | 27 |
| Wt. Sample Wet+Tare | 41.894 | 41.971 | 46.194 |
| Wt. Sample Dry+Tare | 40.500 | 40.649 | 44.309 |
| Wt. Water | 1.394 | 1.322 | 1.885 |
| Tare Container | 35.747 | 36.030 | 37.724 |
| Wt. of Dry Soil | 4.753 | 4.619 | 6.585 |
| Moisture Content % | 29.3 | 28.6 | 28.6 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

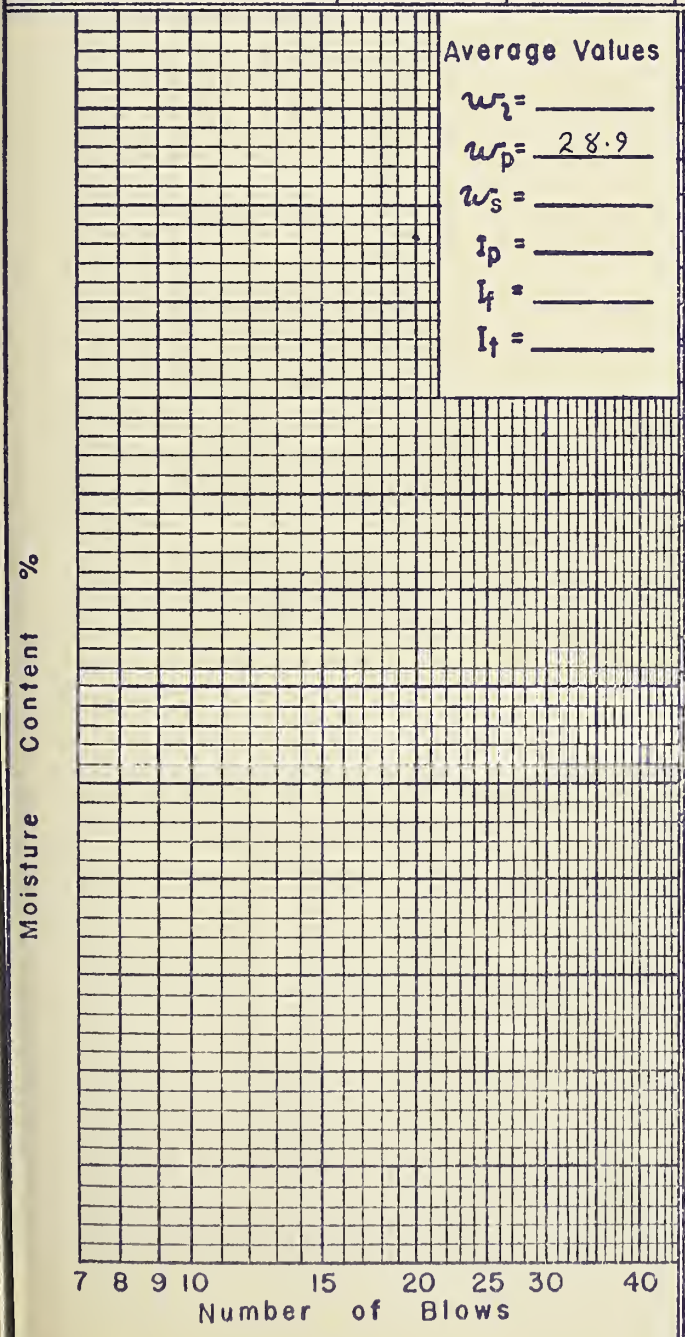
Remarks: Blow count increased as sample worked.

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 2
LOCATION
~~HOLE~~ Cycle # 27 ~~DEPTH~~ Day 31
TECHNICIAN TSW. DATE 24-7-59

### Liquid Limit

| | | | | | | |
|---|---|---|---|---|---|---|
| Trial No. | | | | | | |
| No. of Blows | | | | | | |
| Container No. | | | | | | |
| Wt. Sample Wet + Tare | | | | | | |
| Wt. Sample Dry + Tare | | | | | | |
| Wt. Water | | | | | | |
| Tare Container | | | | | | |
| Wt. of Dry Soil | | | | | | |
| Moisture Content $w$% | | | | | | |




Average Values
$w_l$ = _____
$w_p$ = 28.9
$w_s$ = _____
$I_p$ = _____
$I_f$ = _____
$I_t$ = _____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AD | AE | BL |
| Wt. Sample Wet+Tare | 58.114 | 60.019 | 60.428 |
| Wt. Sample Dry+Tare | 56.817 | 58.460 | 59.150 |
| Wt. Water | 1.297 | 1.559 | 1.278 |
| Tare Container | 52.326 | 53.087 | 54.741 |
| Wt. of Dry Soil | 4.491 | 5.373 | 4.409 |
| Moisture Content % | 28.5 | 29.0 | 29.0 |

### Shrinkage Limit

| | | | |
|---|---|---|---|
| Trial No. | | | |
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

Remarks: _____
, Procedural Check Tests

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest. |
| SITE | Crawford Pit |
| SAMPLE | # 2 |
| LOCATION | |
| ~~HOLE~~ | Cycle #48 DEPTH |
| TECHNICIAN | DS DATE 15-8-59 |

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 35 | 38 | 24 | 16 | 19 | 18 |
| Container No. | V 85 | V 52 | V 71 | V 51 | V 65 | V 77 |
| Wt. Sample Wet + Tare | 105.81 | 103.92 | 102.01 | 91.01 | 91.08 | 100.61 |
| Wt. Sample Dry + Tare | 99.58 | 96.74 | 95.26 | 84.47 | 84.92 | 93.81 |
| Wt. Water | 6.23 | 7.18 | 6.75 | 6.54 | 6.16 | 6.80 |
| Tare Container | 80.42 | 74.82 | 74.63 | 66.13 | 67.88 | 74.80 |
| Wt. of Dry Soil | 19.16 | 21.92 | 20.63 | 18.34 | 17.04 | 19.01 |
| Moisture Content $w$% | 32.5 | 32.7 | 32.7 | 35.6 | 36.1 | 35.8 |

Average Values

$w_l$ = 34.4

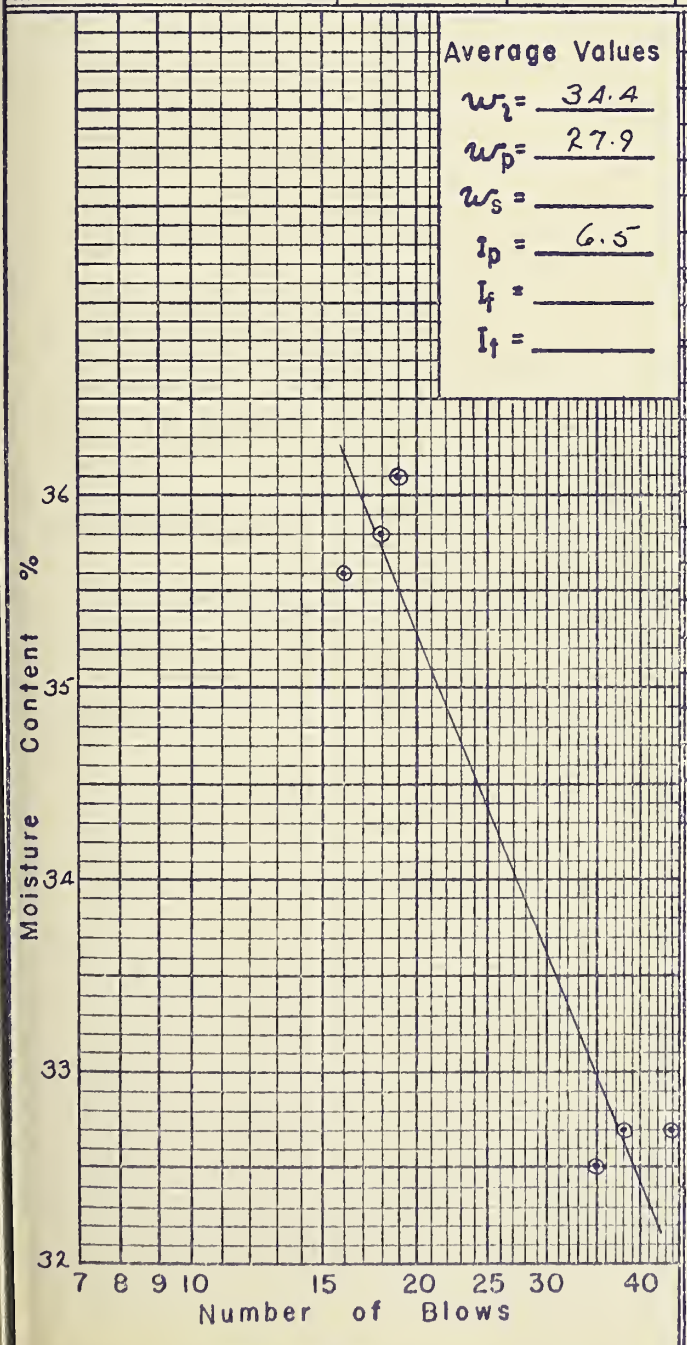
$w_p$ = 27.9

$w_s$ = _____

$I_p$ = 6.5

$I_f$ = _____

$I_t$ = _____




### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | 28 | 22 | 27 |
| Wt. Sample Wet+Tare | 42.397 | 42.152 | 43.526 |
| Wt. Sample Dry+Tare | 41.024 | 40.763 | 42.262 |
| Wt. Water | 1.373 | 1.389 | 1.264 |
| Tare Container | 36.030 | 35.747 | 37.724 |
| Wt. of Dry Soil | 4.994 | 5.016 | 4.438 |
| Moisture Content % | 27.5 | 27.6 | 28.5 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

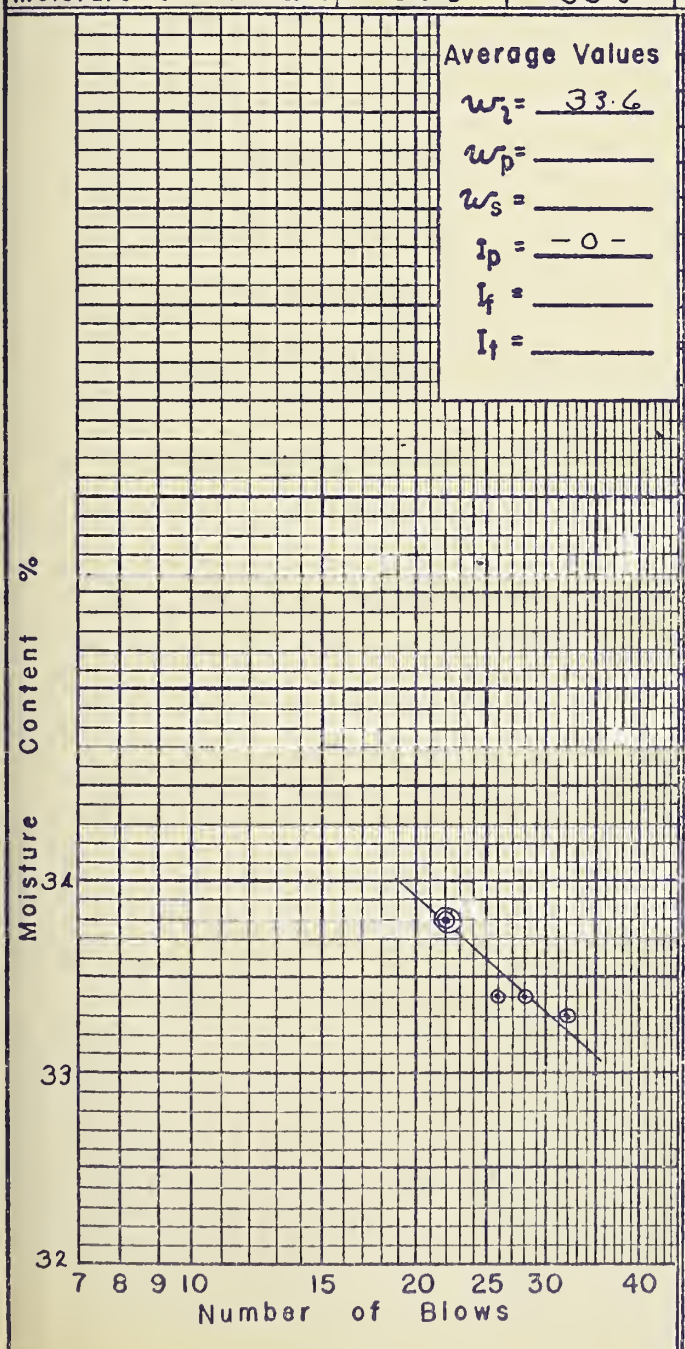
Remarks: _____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest
SITE Crawford Pit
SAMPLE # 3
LOCATION
~~HOLE~~ Cycle # 1 DEPTH Day # 2
TECHNICIAN TSW DATE 25-6-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 22 | 22 | 24 | 26 | 28 | 32 |
| Container No. | V3 | V6 | V7 | V8 | V9 | V10 |
| Wt. Sample Wet + Tare | 87.32 | 100.99 | 97.24 | 87.15 | 108.04 | 100.15 |
| Wt. Sample Dry + Tare | 81.45 | 94.88 | 90.53 | 81.08 | 100.91 | 92.47 |
| Wt. Water | 5.87 | 6.11 | 6.71 | 6.07 | 7.13 | 7.68 |
| Tare Container | 64.10 | 76.78 | 69.16 | 62.91 | 79.58 | 69.43 |
| Wt. of Dry Soil | 17.35 | 18.10 | 21.37 | 18.17 | 21.33 | 23.04 |
| Moisture Content $w$% | 33.8 | 33.8 | 31.4 | 33.4 | 33.4 | 33.3 |




**Average Values**

$w_l$ = 33.6
$w_p$ = _____
$w_s$ = _____
$I_p$ = -0-
$I_f$ = _____
$I_t$ = _____

## Plastic Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | — Non | Plastic | — |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil | | | |
| Moisture Content % | | | |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V - V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V - V_o}{W_o} \times 100\right)$$

Description of Sample: _____

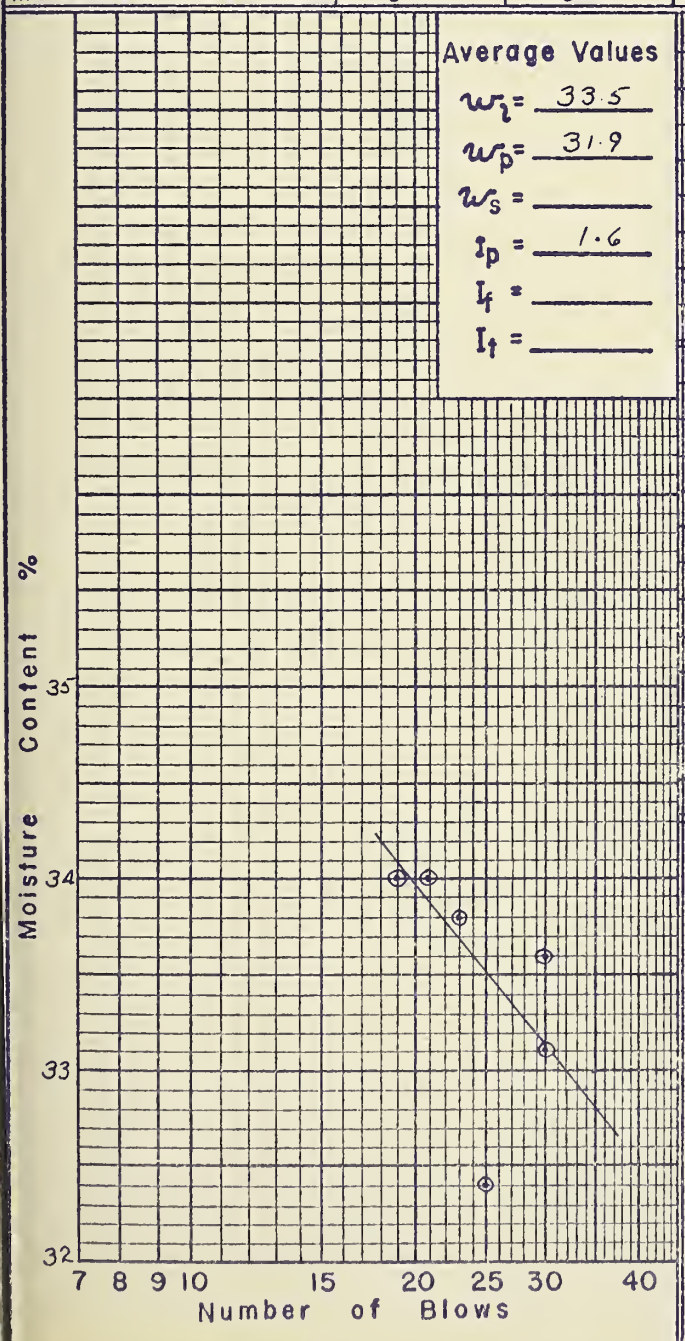
Remarks: _____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 3
LOCATION
~~HOLE~~ Cycle # 3 DEPTH Day 4
TECHNICIAN TSM DATE 27-6-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 19 | 21 | 23 | 25 | 30 | 30 |
| Container No. | V71 | V77 | V62 | V86 | V59 | V52 |
| Wt. Sample Wet + Tare | 97.15 | 101.90 | 87.08 | 93.37 | 88.45 | 96.06 |
| Wt. Sample Dry + Tare | 91.40 | 95.02 | 81.51 | 88.85 | 83.40 | 90.78 |
| Wt. Water | 5.71 | 6.88 | 5.57 | 4.32 | 5.05 | 5.28 |
| Tare Container | 74.63 | 74.80 | 65.05 | 75.50 | 68.38 | 74.82 |
| Wt. of Dry Soil | 16.81 | 20.22 | 16.46 | 13.35 | 15.02 | 15.96 |
| Moisture Content $w$% | 34.0 | 34.0 | 33.8 | 32.4 | 33.6 | 33.1 |




**Average Values**

$w_l$ = 33.5
$w_p$ = 31.9
$w_s$ = ____
$I_p$ = 1.6
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AT | AP | BT |
| Wt. Sample Wet+Tare | 62.479 | 60.106 | 60.452 |
| Wt. Sample Dry+Tare | 60.433 | 58.516 | 61.603 |
| Wt. Water | 2.046 | 1.630 | 2.849 |
| Tare Container | 53.715 | 53.395 | 53.062 |
| Wt. of Dry Soil | 6.718 | 5.121 | 8.541 |
| Moisture Content % | 30.5 | 31.8 | 33.4 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

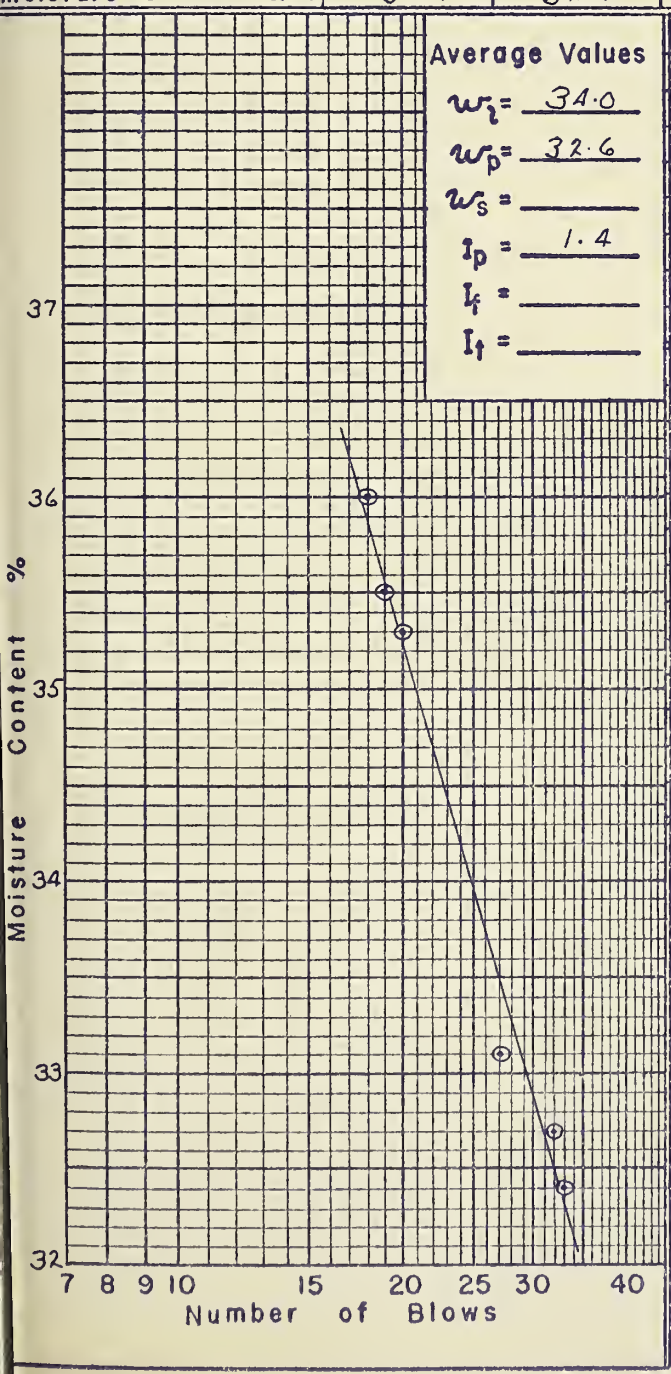
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 3
LOCATION
~~HOLE~~ Cycle # 12 ~~DEPTH~~ Day # 13
TECHNICIAN Tsui DATE 6-7-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 32 | 33 | 27 | 18 | 19 | 20 |
| Container No. | V30 | V6 | V72 | V73 | V47 | V61 |
| Wt. Sample Wet + Tare | 94.59 | 105.87 | 95.66 | 87.68 | 91.00 | 100.57 |
| Wt. Sample Dry + Tare | 88.32 | 98.76 | 89.26 | 82.02 | 83.93 | 94.35 |
| Wt. Water | 6.27 | 7.11 | 6.40 | 5.66 | 7.07 | 6.22 |
| Tare Container | 69.13 | 76.78 | 70.00 | 66.28 | 64.00 | 76.70 |
| Wt. of Dry Soil | 19.19 | 21.98 | 19.26 | 15.74 | 19.93 | 17.65 |
| Moisture Content $w$% | 32.7 | 32.4 | 33.1 | 36.0 | 35.5 | 35.3 |




**Average Values**

$w_l$ = 34.0
$w_p$ = 32.6
$w_s$ = ____
$I_p$ = 1.4
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BE | BT | AH |
| Wt. Sample Wet+Tare | 64.301 | 62.401 | 61.902 |
| Wt. Sample Dry+Tare | 61.840 | 60.097 | 59.519 |
| Wt. Water | 2.461 | 2.304 | 2.383 |
| Tare Container | 54.381 | 53.062 | 52.057 |
| Wt. of Dry Soil | 7.459 | 7.035 | 7.462 |
| Moisture Content % | 33.0 | 32.8 | 32.0 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

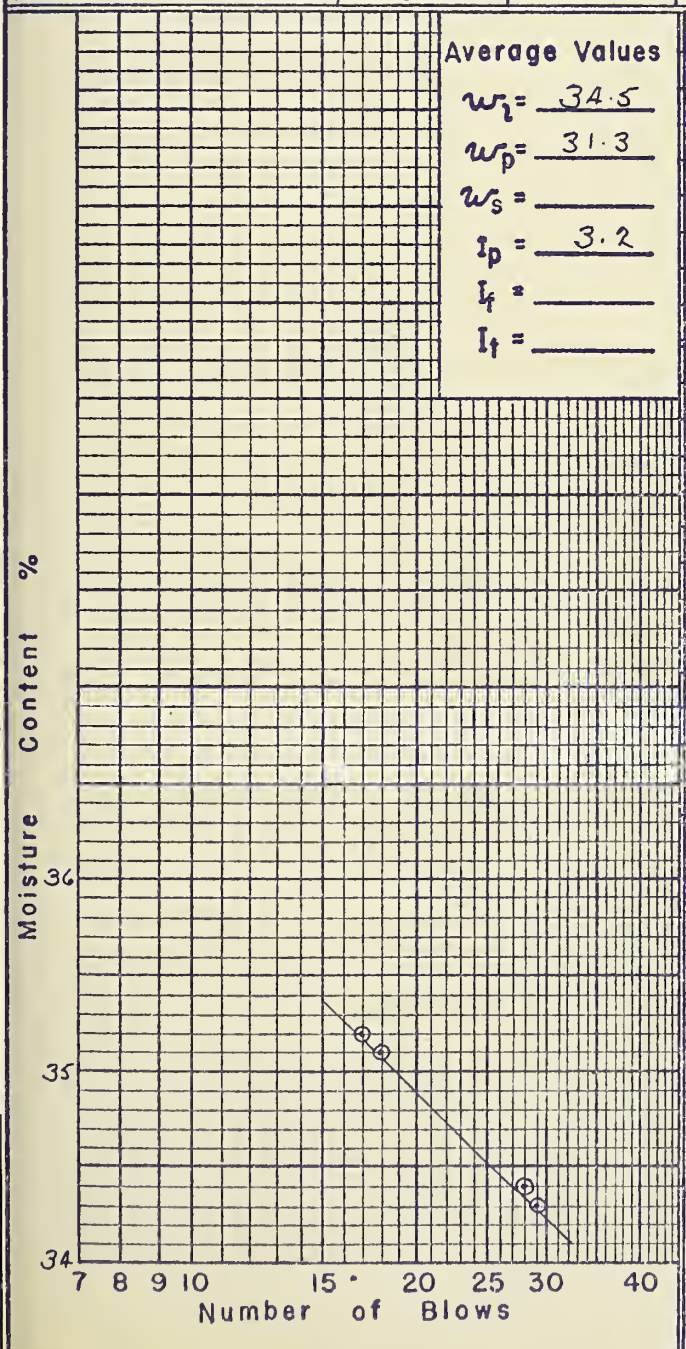
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest. |
| SITE | Crawford Pit |
| SAMPLE | #3 |
| LOCATION | |
| ~~HOLE~~ | Cycle # 25 ~~DEPTH~~ Day 29 |
| TECHNICIAN | DS DATE 22-7-59 |

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 17 | 18 | 17 | 28 | 28 | 29 |
| Container No. | V86 | V70 | V84 | V90 | V9 | V46 |
| Wt. Sample Wet + Tare | 99.47 | 109.23 | 104.65 | 97.71 | 106.23 | 110.20 |
| Wt. Sample Dry + Tare | 93.23 | 102.21 | 97.03 | 91.34 | 99.40 | 103.44 |
| Wt. Water | 6.24 | 7.02 | 7.62 | 6.37 | 6.83 | 6.76 |
| Tare Container | 75.50 | 82.18 | 75.38 | 72.80 | 79.58 | 83.71 |
| Wt. of Dry Soil | 17.73 | 20.03 | 21.65 | 18.54 | 19.82 | 19.73 |
| Moisture Content w% | 35.2 | 35.1 | 35.2 | 34.4 | 34.4 | 34.3 |




**Average Values**

$w_l$ = 34.5

$w_p$ = 31.3

$w_s$ = _____

$I_p$ = 3.2

$I_f$ = _____

$I_t$ = _____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AS | BI | BK |
| Wt. Sample Wet+Tare | 60.010 | 61.842 | 59.893 |
| Wt. Sample Dry+Tare | 58.630 | 60.200 | 58.308 |
| Wt. Water | 1.380 | 1.642 | 1.585 |
| Tare Container | 54.249 | 54.942 | 53.262 |
| Wt. of Dry Soil | 4.381 | 5.258 | 5.046 |
| Moisture Content % | 31.5 | 31.2 | 31.4 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content w% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____
Blow count tends to increase with working. Moisture migrates to bottom of sample when standing.

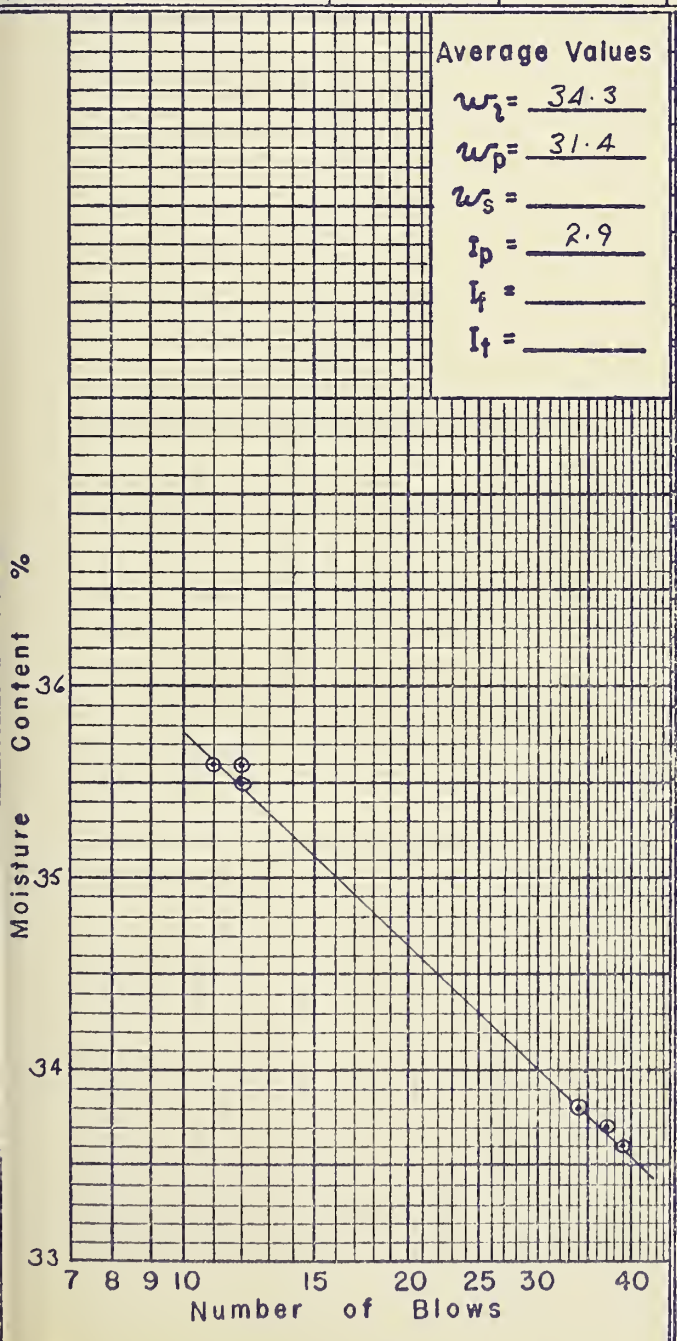
Remarks: _____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest. |
| SITE | Crawford Pit |
| SAMPLE | # 3 |
| LOCATION | |
| ~~HOLE~~ | Cycle 48 ~~DEPTH~~ Day 54 |
| TECHNICIAN | T.S.W. DATE 16-8-59 |

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 11 | 12 | 12 | 34 | 39 | 37 |
| Container No. | V48 | V74 | V80 | V85 | V68 | V50 |
| Wt. Sample Wet + Tare | 91.57 | 97.82 | 101.88 | 105.30 | 109.63 | 105.57 |
| Wt. Sample Dry + Tare | 85.72 | 90.82 | 94.06 | 99.01 | 103.90 | 99.52 |
| Wt. Water | 5.85 | 7.00 | 7.82 | 6.29 | 5.63 | 6.05 |
| Tare Container | 69.29 | 71.11 | 72.00 | 80.42 | 87.13 | 81.54 |
| Wt. of Dry Soil | 16.43 | 19.71 | 22.06 | 18.59 | 16.77 | 17.98 |
| Moisture Content $w$% | 35.6 | 35.6 | 35.5 | 33.8 | 33.6 | 33.7 |




**Average Values**

$w_l$ = 34.3

$w_p$ = 31.4

$w_s$ = _____

$I_p$ = 2.9

$I_f$ = _____

$I_t$ = _____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BK | AS | BI |
| Wt. Sample Wet+Tare | 61.102 | 64.241 | 65.568 |
| Wt. Sample Dry+Tare | 59.247 | 61.832 | 63.004 |
| Wt. Water | 1.855 | 2.409 | 2.564 |
| Tare Container | 53.262 | 54.249 | 54.942 |
| Wt. of Dry Soil | 5.985 | 7.583 | 8.062 |
| Moisture Content % | 31.0 | 31.4 | 31.8 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

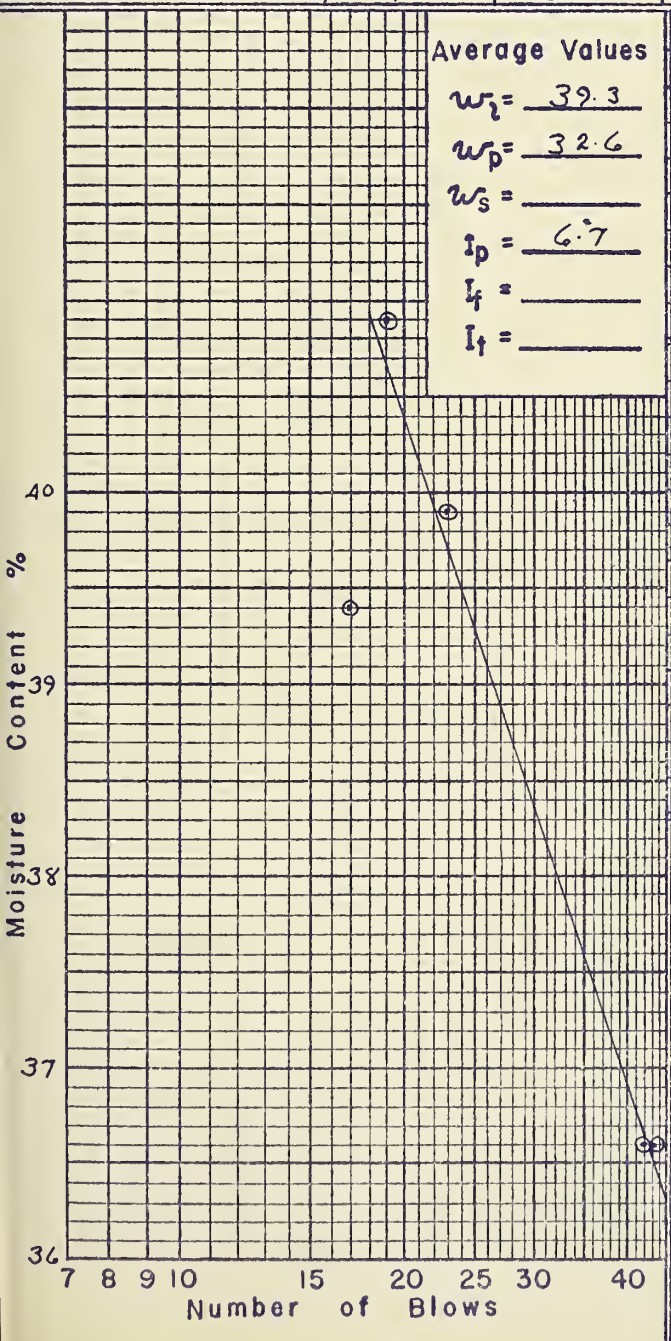
Remarks: _____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # A
LOCATION
~~HOLE~~ Cycle # 1 ~~DEPTH~~ Day # 3
TECHNICIAN TSW. DATE 3-6-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 46 | 42 | 43 | 23 | 17 | 19 |
| Container No. | V86 | V65 | V66 | V52 | V57 | V58 |
| Wt. Sample Wet + Tare | 104.37 | 90.82 | 92.83 | 102.04 | 96.57 | 105.57 |
| Wt. Sample Dry + Tare | 96.66 | 84.67 | 85.75 | 94.28 | 89.10 | 95.13 |
| Wt. Water | 8.71 | 6.15 | 7.08 | 7.76 | 7.47 | 10.44 |
| Tare Container | 75.50 | 67.88 | 66.43 | 74.82 | 70.91 | 69.63 |
| Wt. of Dry Soil | 21.16 | 16.79 | 19.32 | 19.46 | 18.99 | 25.50 |
| Moisture Content w% | 41.2 | 36.6 | 36.6 | 39.9 | 39.4 | 40.9 |




Average Values
$w_l$ = 39.3
$w_p$ = 32.6
$w_s$ = ____
$I_p$ = 6.7
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AT | AP | BL |
| Wt. Sample Wet+Tare | 65.582 | 62.632 | 66.733 |
| Wt. Sample Dry+Tare | 62.588 | 60.363 | 63.800 |
| Wt. Water | 2.994 | 2.269 | 2.933 |
| Tare Container | 53.715 | 53.395 | 54.741 |
| Wt. of Dry Soil | 8.873 | 6.968 | 9.057 |
| Moisture Content % | 33.7 | 32.6 | 32.4 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content w% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

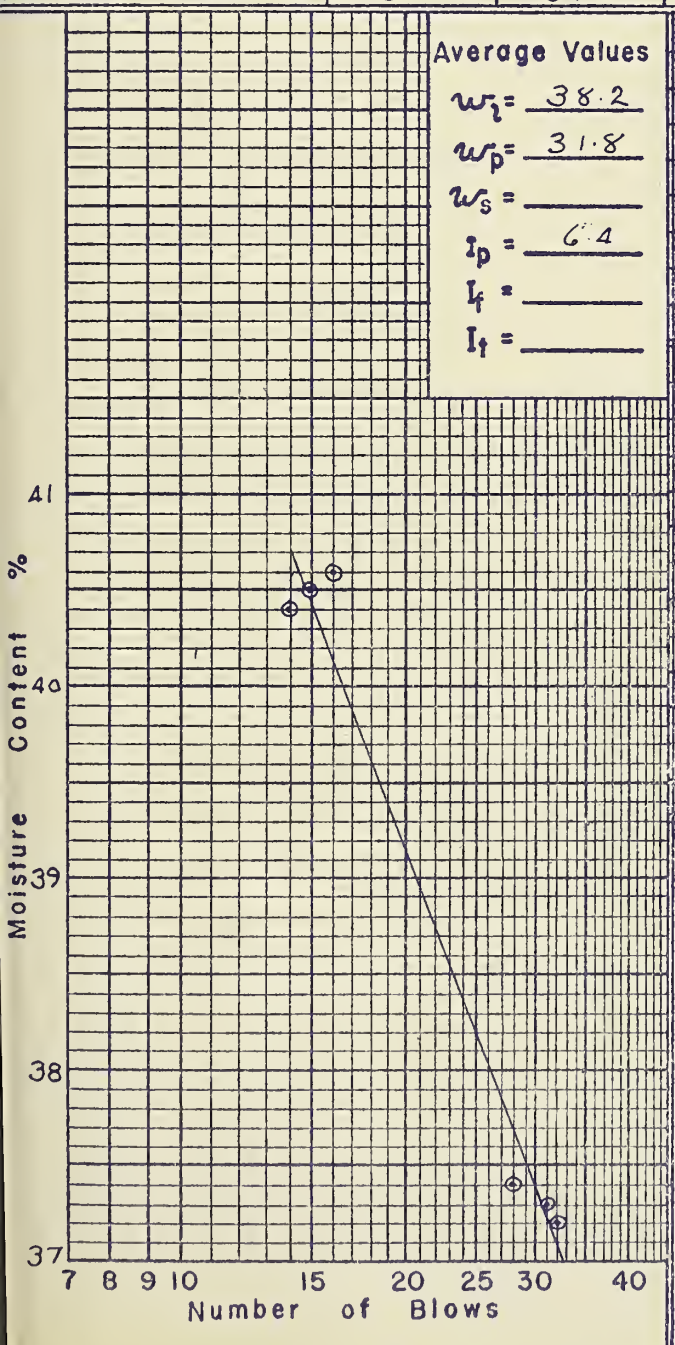
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 4
LOCATION
~~HOLE~~ Cycle # 3 ~~DEPTH~~ Day 5
TECHNICIAN TSW DATE 28-6-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 28 | 32 | 31 | 16 | 15 | 14 |
| Container No. | V10 | V74 | V58 | V70 | V65 | V69 |
| Wt. Sample Wet + Tare | 91.70 | 89.81 | 89.63 | 106.02 | 89.27 | 93.26 |
| Wt. Sample Dry + Tare | 85.64 | 84.73 | 84.20 | 99.13 | 83.10 | 86.40 |
| Wt. Water | 6.06 | 5.08 | 5.43 | 6.89 | 6.17 | 6.86 |
| Tare Container | 69.43 | 71.11 | 69.63 | 82.18 | 67.88 | 69.41 |
| Wt. of Dry Soil | 16.21 | 13.62 | 14.57 | 15.95 | 15.22 | 16.99 |
| Moisture Content w% | 37.4 | 37.2 | 37.3 | 40.6 | 40.5 | 40.4 |




Average Values
$w_l$ = 38.2
$w_p$ = 31.8
$w_s$ = ____
$I_p$ = 6.4
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BT | BA | AD |
| Wt. Sample Wet+Tare | 58.933 | 58.858 | 60.403 |
| Wt. Sample Dry+Tare | 57.568 | 57.156 | 58.427 |
| Wt. Water | 1.365 | 1.702 | 1.976 |
| Tare Container | 53.062 | 51.756 | 52.326 |
| Wt. of Dry Soil | 4.506 | 5.400 | 6.101 |
| Moisture Content % | 30.3 | 31.5 | 32.2 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content w% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

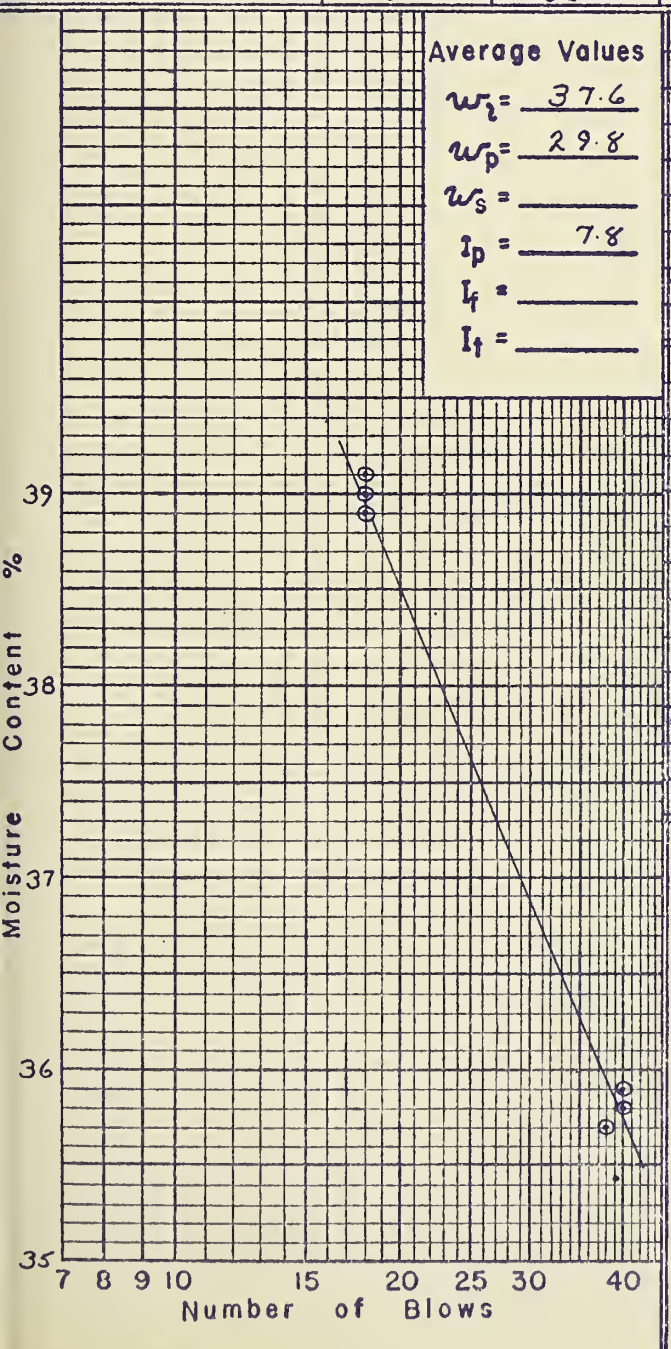
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 4
LOCATION
~~HOLE~~ Cycle # 12 ~~DEPTH~~ Day 14
TECHNICIAN TSW DATE 7-7-59

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 40 | 38 | 40 | 18 | 18 | 18 |
| Container No. | V81 | V7 | V84 | V63 | V90 | V85 |
| Wt. Sample Wet + Tare | 97.87 | 89.14 | 98.77 | 91.16 | 97.90 | 112.33 |
| Wt. Sample Dry + Tare | 92.14 | 83.88 | 92.59 | 84.60 | 90.87 | 103.37 |
| Wt. Water | 5.73 | 5.26 | 6.18 | 6.56 | 7.03 | 8.96 |
| Tare Container | 76.19 | 69.16 | 75.38 | 67.80 | 72.80 | 80.42 |
| Wt. of Dry Soil | 15.95 | 14.72 | 17.21 | 16.80 | 18.07 | 22.95 |
| Moisture Content w% | 35.9 | 35.7 | 35.8 | 39.1 | 38.9 | 39.0 |




**Average Values**

$w_l$ = 37.6
$w_p$ = 29.8
$w_s$ = ____
$I_p$ = 7.8
$I_f$ = ____
$I_t$ = ____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AH | AC | AD |
| Wt. Sample Wet+Tare | 60.304 | 62.319 | 59.483 |
| Wt. Sample Dry+Tare | 58.358 | 60.193 | 57.839 |
| Wt. Water | 1.946 | 2.126 | 1.644 |
| Tare Container | 52.057 | 53.639 | 52.326 |
| Wt. of Dry Soil | 6.301 | 6.554 | 5.513 |
| Moisture Content % | 30.9 | 32.2 | 29.8 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

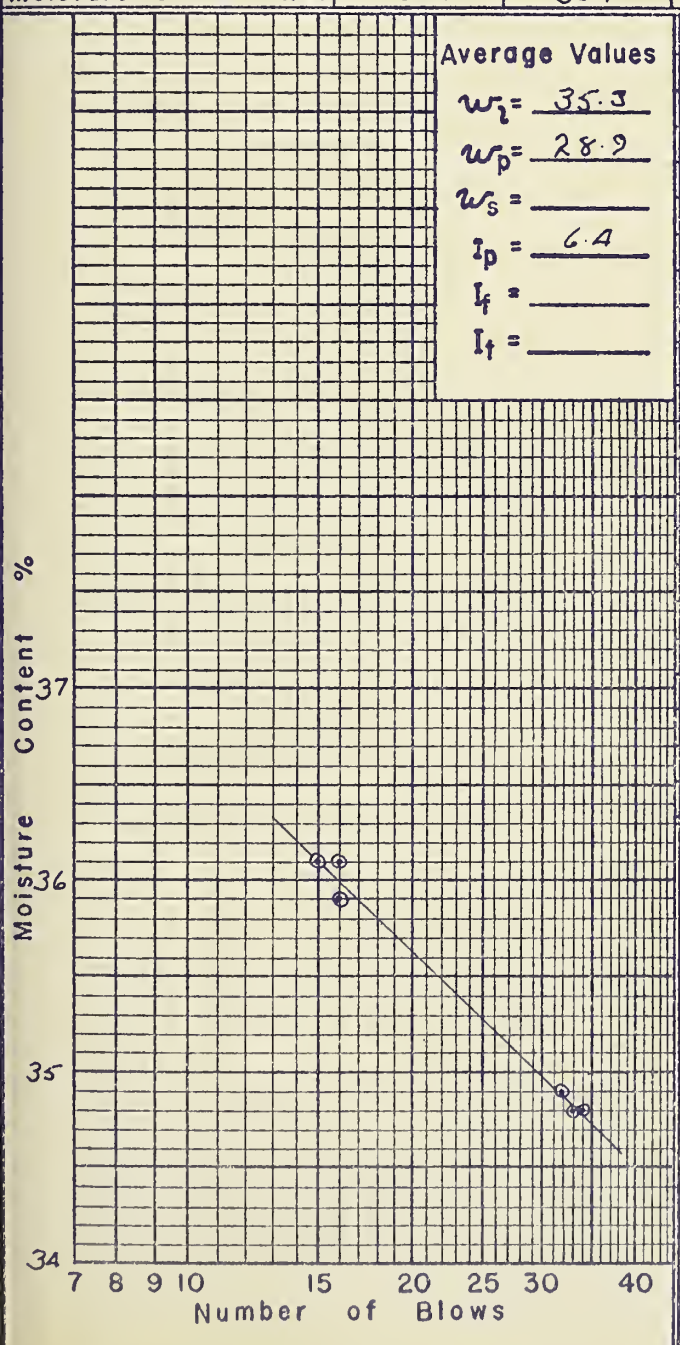
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 4
LOCATION
~~HOLE~~ Cycle # 25 DEPTH
TECHNICIAN T.S.L. DATE 23-7-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 16 | 15 | 16 | 32 | 34 | 33 |
| Container No. | V80 | V85 | V50 | V48 | V68 | V74 |
| Wt. Sample Wet + Tare | 96.37 | 108.66 | 106.44 | 96.77 | 113.84 | 97.68 |
| Wt. Sample Dry + Tare | 89.93 | 101.18 | 99.86 | 89.66 | 106.94 | 90.82 |
| Wt. Water | 6.44 | 7.48 | 6.58 | 7.11 | 6.90 | 6.86 |
| Tare Container | 72.00 | 80.42 | 81.54 | 69.29 | 87.13 | 71.11 |
| Wt. of Dry Soil | 17.93 | 20.76 | 18.32 | 20.37 | 19.81 | 19.71 |
| Moisture Content $w$% | 36.1 | 36.1 | 35.9 | 34.9 | 34.8 | 34.8 |




Average Values
$w_l$ = 35.3
$w_p$ = 28.9
$w_s$ = ____
$I_p$ = 6.4
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AC | BR | AH |
| Wt. Sample Wet+Tare | 59.474 | 57.837 | 57.824 |
| Wt. Sample Dry+Tare | 58.173 | 56.458 | 56.537 |
| Wt. Water | 1.301 | 1.379 | 1.287 |
| Tare Container | 53.693 | 51.756 | 52.057 |
| Wt. of Dry Soil | 4.480 | 4.702 | 4.480 |
| Moisture Content % | 29.0 | 29.2 | 28.7 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: Definate structural change occurs in F.T. sample. Darker color. Water separates out. Material has structural strength, is friable & non plastic. On working it tends to revert to more plastic state similair to time control sample.

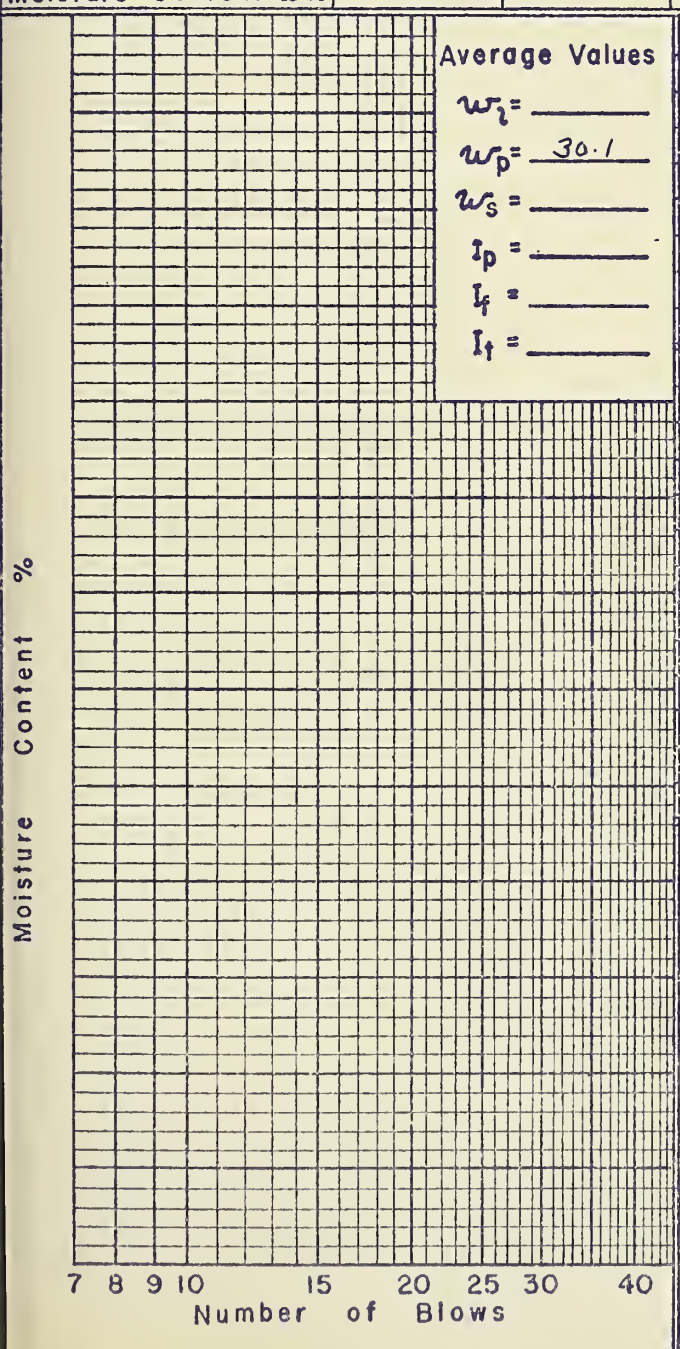
Remarks:

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 4
LOCATION
HOLE Cycle # 26 DEPTH
TECHNICIAN TSM DATE 24-7-59

### Liquid Limit

| | | | | | | |
|---|---|---|---|---|---|---|
| Trial No. | | | | | | |
| No. of Blows | | | | | | |
| Container No. | | | | | | |
| Wt. Sample Wet + Tare | | | | | | |
| Wt. Sample Dry + Tare | | | | | | |
| Wt. Water | | | | | | |
| Tare Container | | | | | | |
| Wt. of Dry Soil | | | | | | |
| Moisture Content $w$% | | | | | | |




Average Values
$w_l$ = _____
$w_p$ = 30.1
$w_s$ = _____
$I_p$ = _____
$I_f$ = _____
$I_t$ = _____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BR | RH | RC |
| Wt. Sample Wet+Tare | 58.057 | 58.612 | 61.107 |
| Wt. Sample Dry+Tare | 56.601 | 57.121 | 59.364 |
| Wt. Water | 1.456 | 1.491 | 1.743 |
| Tare Container | 51.756 | 52.057 | 53.639 |
| Wt. of Dry Soil | 4.845 | 5.064 | 5.625 |
| Moisture Content % | 30.1 | 29.4 | 31.0 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

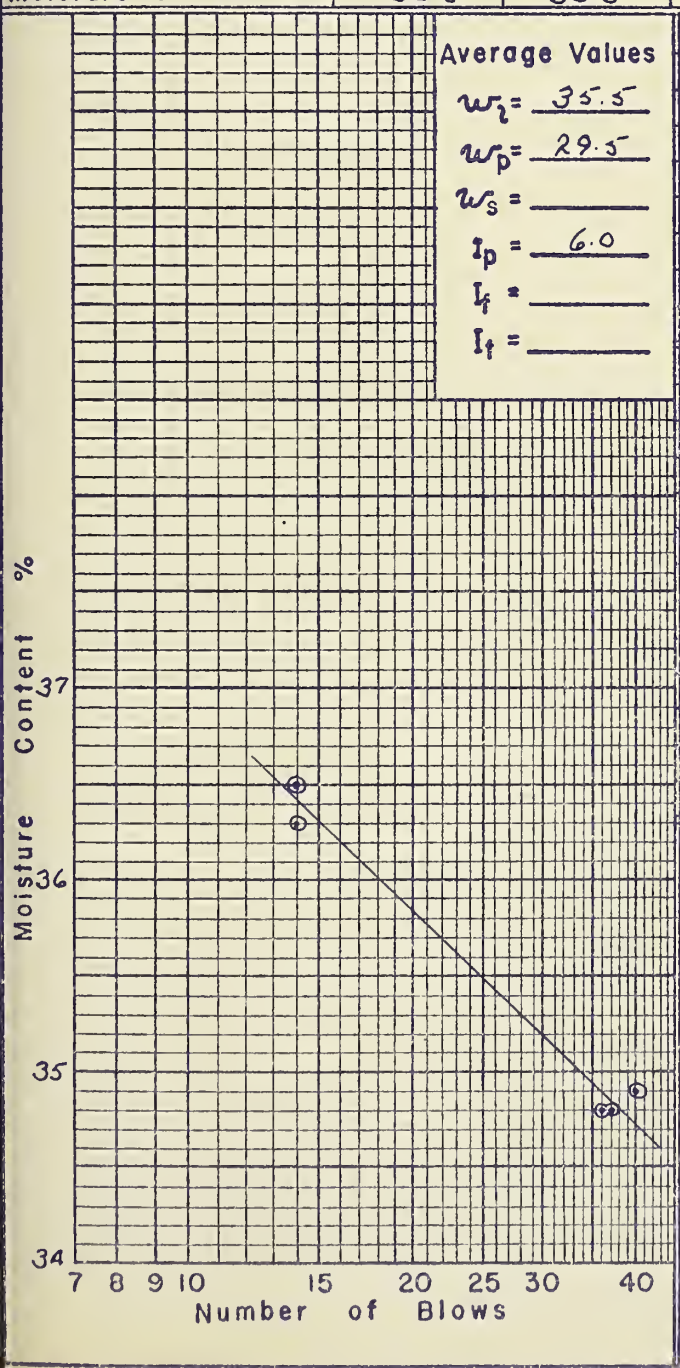
Remarks: _____
Check Tests on WP

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 4
LOCATION
HOLE Cycle # 48 DEPTH
TECHNICIAN TSW DATE 16-8-59

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 14 | 14 | 14 | 36 | 37 | 40 |
| Container No. | V52 | V66 | V36 | V46 | V83 | V73 |
| Wt. Sample Wet + Tare | 94.40 | 88.70 | 87.55 | 103.90 | 94.00 | 87.99 |
| Wt. Sample Dry + Tare | 89.17 | 82.78 | 82.10 | 98.70 | 88.10 | 82.38 |
| Wt. Water | 5.23 | 5.92 | 5.45 | 5.20 | 5.90 | 5.61 |
| Tare Container | 74.82 | 66.43 | 67.04 | 83.71 | 71.16 | 66.28 |
| Wt. of Dry Soil | 14.35 | 16.35 | 15.06 | 14.99 | 16.94 | 16.10 |
| Moisture Content $w$% | 36.5 | 36.3 | 36.3 | 34.8 | 34.8 | 34.9 |




Average Values
$w_l$ = 35.5
$w_p$ = 29.5
$w_s$ = ____
$I_p$ = 6.0
$I_f$ = ____
$I_t$ = ____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BE | AC | AM |
| Wt. Sample Wet+Tare | 61.679 | 61.737 | 62.270 |
| Wt. Sample Dry+Tare | 60.024 | 59.903 | 60.179 |
| Wt. Water | 1.655 | 1.834 | 2.091 |
| Tare Container | 54.381 | 53.639 | 53.162 |
| Wt. of Dry Soil | 5.643 | 6.264 | 7.017 |
| Moisture Content % | 29.3 | 29.3 | 29.8 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

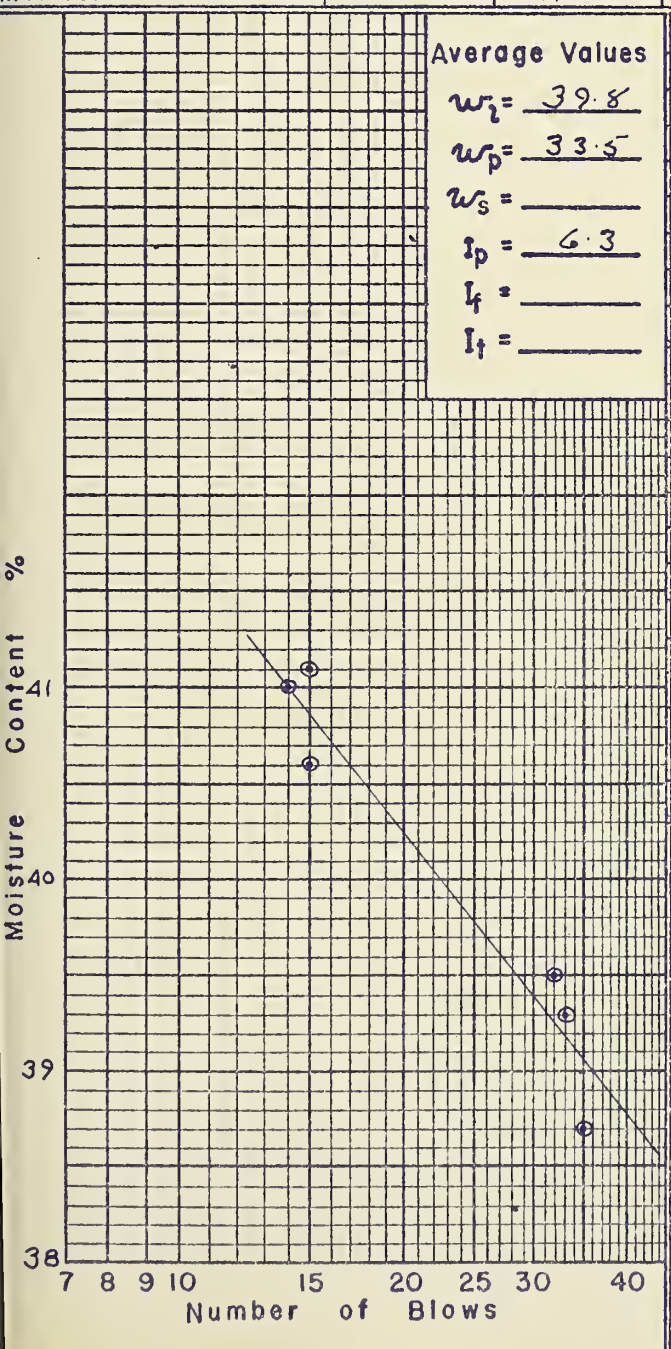
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 5
LOCATION
~~HOLE~~ Cycle # 1 DEPTH
TECHNICIAN J.S DATE 26-6-59

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 14 | 15 | 15 | 32 | 33 | 35 |
| Container No. | V59 | V51 | V50 | V90 | V81 | V84 |
| Wt. Sample Wet + Tare | 87.40 | 80.47 | 95.73 | 89.54 | 90.87 | 89.82 |
| Wt. Sample Dry + Tare | 81.87 | 76.30 | 91.63 | 84.80 | 86.73 | 85.79 |
| Wt. Water | 5.53 | 4.17 | 4.10 | 4.74 | 4.14 | 4.03 |
| Tare Container | 68.38 | 66.13 | 81.54 | 72.80 | 76.19 | 75.38 |
| Wt. of Dry Soil | 13.49 | 10.17 | 10.09 | 12.00 | 10.54 | 10.41 |
| Moisture Content w% | 41.0 | 41.1 | 40.6 | 39.5 | 39.3 | 38.7 |




Average Values
$w_l$ = 39.8
$w_p$ = 33.5
$w_s$ = ____
$I_p$ = 6.3
$I_f$ = ____
$I_t$ = ____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BA | BK | AS |
| Wt. Sample Wet+Tare | 60.975 | 61.477 | 61.552 |
| Wt. Sample Dry+Tare | 58.696 | 59.419 | 59.688 |
| Wt. Water | 2.279 | 2.058 | 1.864 |
| Tare Container | 51.756 | 53.262 | 54.249 |
| Wt. of Dry Soil | 6.940 | 6.157 | 5.439 |
| Moisture Content % | 32.8 | 33.4 | 34.3 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content w% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

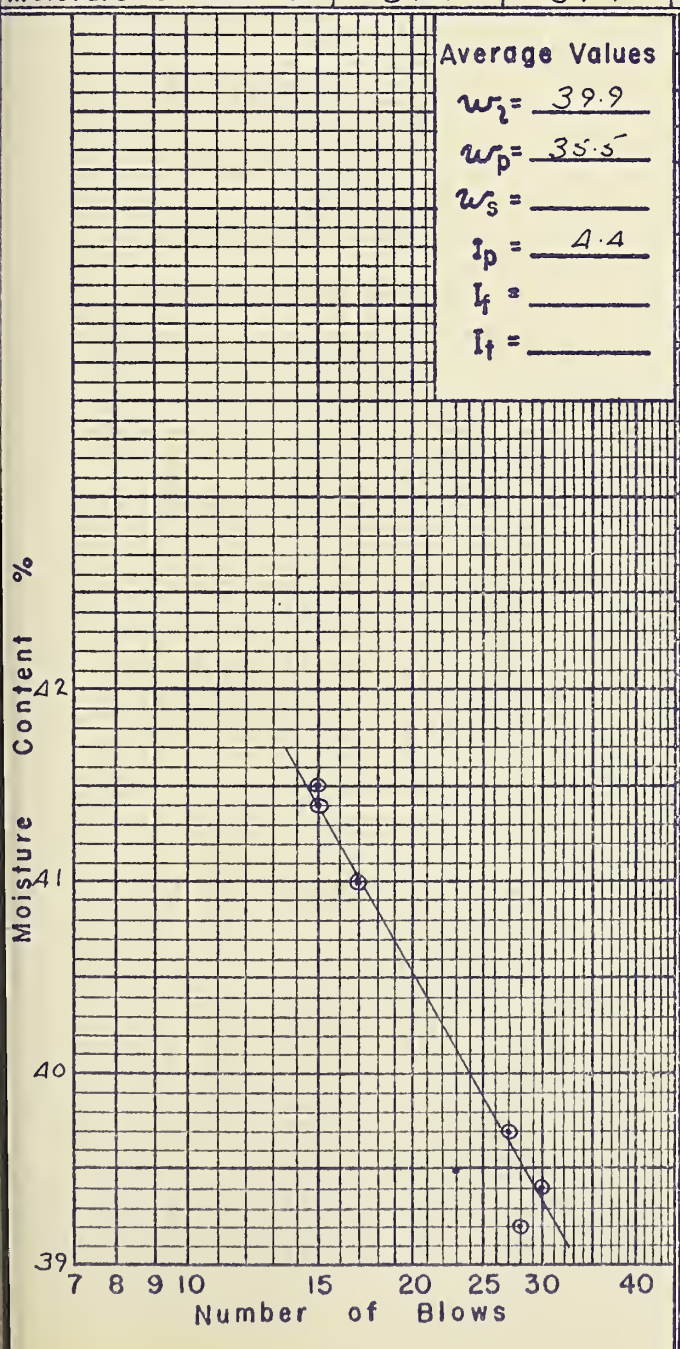
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crowford Pit
SAMPLE # 5
LOCATION
~~HOLE~~ Cycle # 3 DEPTH
TECHNICIAN D.S DATE 28-6-59

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 30 | 27 | 28 | 15 | 15 | 17 |
| Container No. | V 77 | V 71 | V 52 | V 86 | V 62 | V 59 |
| Wt. Sample Wet + Tare | 90.11 | 91.48 | 89.51 | 91.67 | 78.68 | 79.90 |
| Wt. Sample Dry + Tare | 85.78 | 86.69 | 85.38 | 86.92 | 74.69 | 76.55 |
| Wt. Water | 4.33 | 4.79 | 4.13 | 4.75 | 3.99 | 3.35 |
| Tare Container | 74.80 | 74.63 | 74.82 | 75.50 | 65.05 | 68.38 |
| Wt. of Dry Soil | 10.98 | 12.06 | 10.56 | 11.42 | 9.64 | 8.17 |
| Moisture Content $w$% | 39.4 | 39.7 | 39.2 | 41.5 | 41.4 | 41.0 |




Average Values
$w_l$ = 39.9
$w_p$ = 35.5
$w_s$ = ____
$I_p$ = 4.4
$I_f$ = ____
$I_t$ = ____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | 28 | AP | 22 |
| Wt. Sample Wet+Tare | 46.812 | 67.747 | 49.339 |
| Wt. Sample Dry+Tare | 43.959 | 64.018 | 45.778 |
| Wt. Water | 2.853 | 3.729 | 3.556 |
| Tare Container | 36.030 | 53.395 | 35.747 |
| Wt. of Dry Soil | 7.929 | 10.623 | 10.031 |
| Moisture Content % | 36.0 | 35.1 | 35.4 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

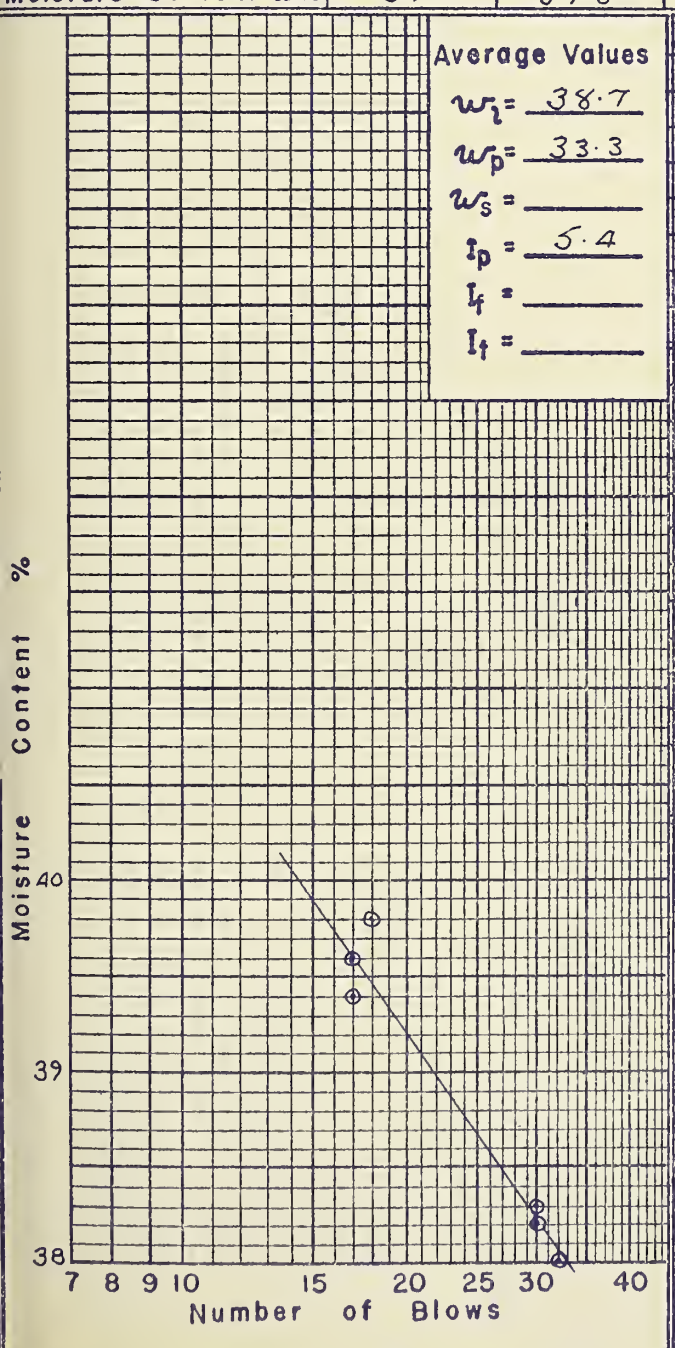
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest. |
| SITE | Crawford Pit |
| SAMPLE | # 5 |
| LOCATION | |
| ~~HOLE~~ | Cycle # 12 DEPTH |
| TECHNICIAN | DS DATE 7-7-59 |

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 17 | 18 | 17 | 30 | 30 | 32 |
| Container No. | V58 | V65 | V68 | V50 | V69 | V10 |
| Wt. Sample Wet + Tare | 80.97 | 80.29 | 98.03 | 98.46 | 83.89 | 87.44 |
| Wt. Sample Dry + Tare | 77.75 | 76.76 | 94.95 | 93.78 | 79.88 | 82.48 |
| Wt. Water | 3.22 | 3.53 | 3.08 | 4.68 | 4.01 | 4.96 |
| Tare Container | 69.63 | 67.88 | 87.13 | 81.54 | 69.41 | 69.43 |
| Wt. of Dry Soil | 8.12 | 8.88 | 7.82 | 12.24 | 10.47 | 13.05 |
| Moisture Content $w$% | 39.6 | 39.8 | 39.4 | 38.2 | 38.3 | 38.0 |




**Average Values**

$w_l$ = 38.7

$w_p$ = 33.3

$w_s$ = _____

$I_p$ = 5.4

$I_f$ = _____

$I_t$ = _____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | 2 | BK | 1 |
| Wt. Sample Wet+Tare | 48.812 | 63.057 | 45.381 |
| Wt. Sample Dry+Tare | 45.602 | 60.637 | 42.934 |
| Wt. Water | 3.210 | 2.420 | 2.447 |
| Tare Container | 36.010 | 53.262 | 35.680 |
| Wt. of Dry Soil | 9.592 | 7.395 | 7.254 |
| Moisture Content % | 33.4 | 32.8 | 33.7 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

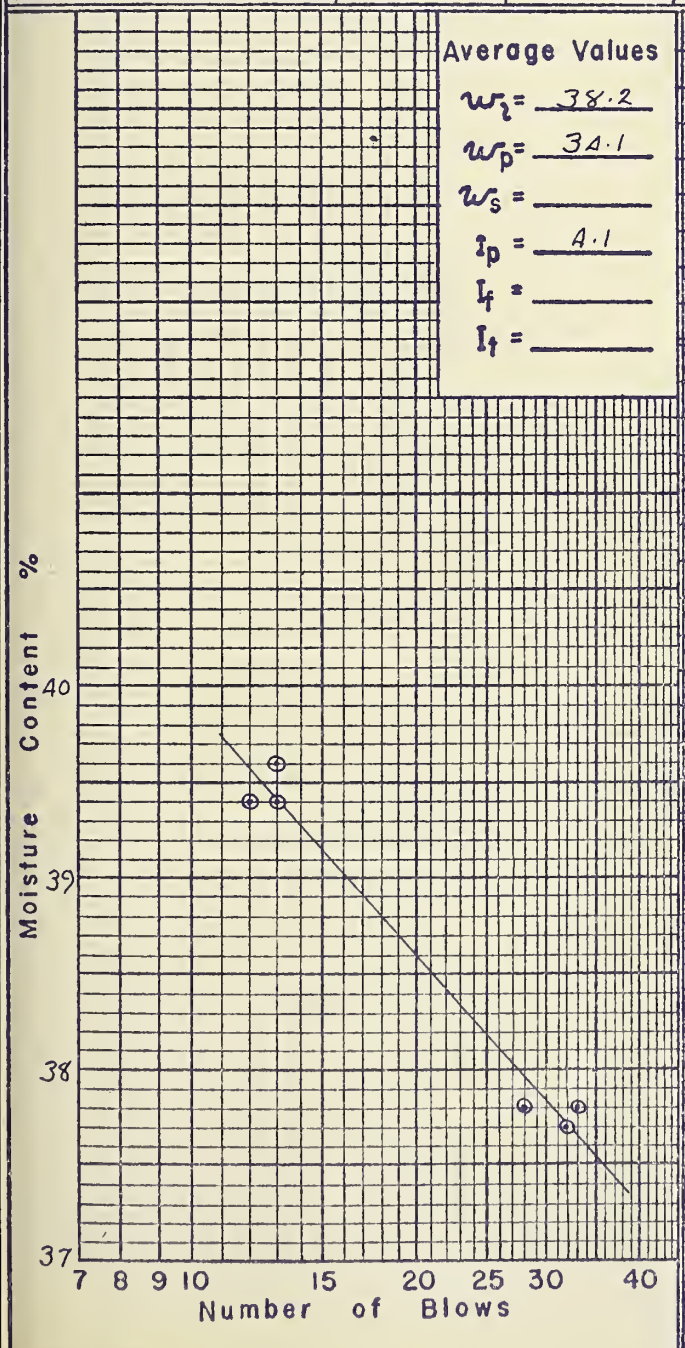
Remarks: _____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 5
LOCATION
~~HOLE~~ Cycle # 25 DEPTH
TECHNICIAN JS DATE 23-7-59

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 12 | 13 | 13 | 28 | 33 | 32 |
| Container No. | V52 | V51 | V65 | V78 | V77 | V3 |
| Wt. Sample Wet + Tare | 94.94 | 92.58 | 91.03 | 103.22 | 93.71 | 85.88 |
| Wt. Sample Dry + Tare | 89.26 | 85.08 | 84.49 | 97.61 | 88.53 | 79.92 |
| Wt. Water | 5.68 | 7.50 | 6.54 | 5.61 | 5.18 | 5.96 |
| Tare Container | 74.82 | 66.13 | 67.88 | 82.78 | 74.80 | 64.10 |
| Wt. of Dry Soil | 14.44 | 18.95 | 16.61 | 14.83 | 13.73 | 15.82 |
| Moisture Content $w$% | 39.4 | 39.6 | 39.4 | 37.8 | 37.8 | 37.7 |




**Average Values**

$w_l$ = 38.2
$w_p$ = 34.1
$w_s$ = ____
$I_p$ = 4.1
$I_f$ = ____
$I_t$ = ____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BK | AT | AY |
| Wt. Sample Wet+Tare | 58.008 | 59.019 | 60.217 |
| Wt. Sample Dry+Tare | 56.789 | 57.658 | 58.768 |
| Wt. Water | 1.219 | 1.361 | 1.449 |
| Tare Container | 53.262 | 53.715 | 54.431 |
| Wt. of Dry Soil | 3.527 | 3.943 | 4.337 |
| Moisture Content % | 34.5 | 34.5 | 33.4 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

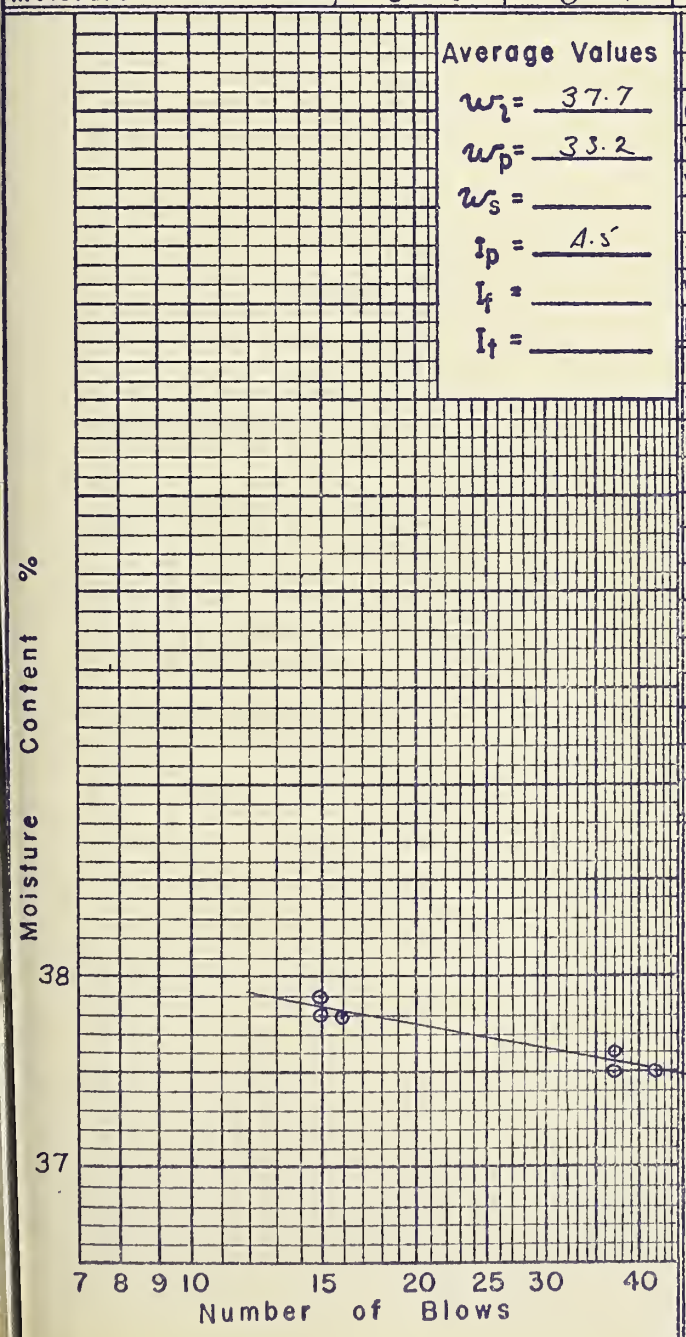
Remarks: Water drains out of freeze thaw sample leaving material firm and relatively dry

# UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 5
LOCATION
~~HOLE~~ Cycle # 48 DEPTH
TECHNICIAN DS DATE 17-8-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 16 | 15 | 15 | 37 | 37 | 42 |
| Container No. | V72 | V7 | V42 | V9 | V69 | V88 |
| Wt. Sample Wet + Tare | 93.38 | 90.88 | 92.28 | 101.46 | 90.50 | 102.47 |
| Wt. Sample Dry + Tare | 86.96 | 84.91 | 85.46 | 95.48 | 84.75 | 95.64 |
| Wt. Water | 6.42 | 5.97 | 6.82 | 5.98 | 5.75 | 6.83 |
| Tare Container | 70.00 | 69.16 | 67.38 | 79.58 | 69.41 | 77.43 |
| Wt. of Dry Soil | 16.96 | 15.95 | 18.08 | 15.90 | 15.35 | 18.21 |
| Moisture Content $w$% | 37.8 | 37.9 | 37.8 | 37.6 | 37.5 | 37.5 |




Average Values
$w_l$ = 37.7
$w_p$ = 33.2
$w_s$ = ____
$I_p$ = 4.5
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BA | AV | AP |
| Wt. Sample Wet+Tare | 59.915 | 61.490 | 59.679 |
| Wt. Sample Dry+Tare | 57.900 | 59.730 | 58.098 |
| Wt. Water | 2.015 | 1.760 | 1.581 |
| Tare Container | 51.756 | 54.431 | 53.395 |
| Wt. of Dry Soil | 6.144 | 5.299 | 4.703 |
| Moisture Content % | 32.8 | 33.2 | 33.6 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

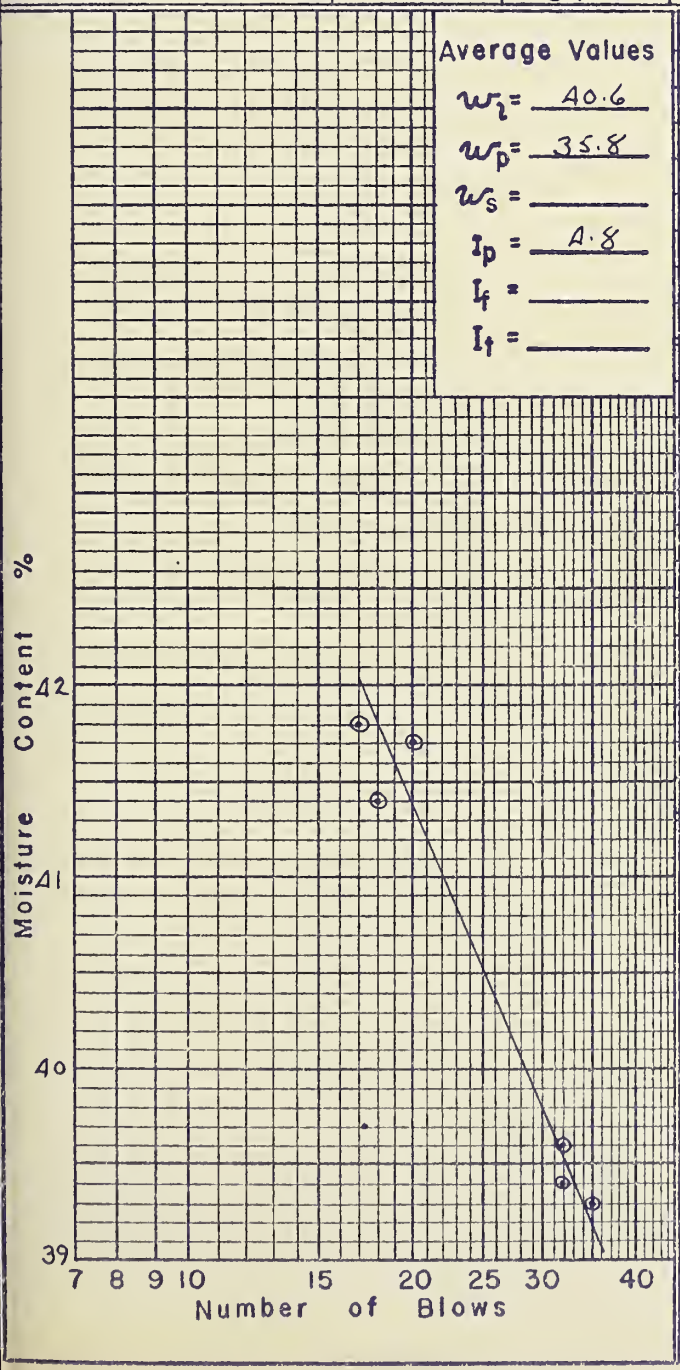
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest |
| SITE | Crawford Pit |
| SAMPLE | # 6 |
| LOCATION | |
| ~~HOLE~~ | Cycle # 1 ~~DEPTH~~ Day 3 |
| TECHNICIAN | TSL DATE 26-6-59 |

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 32 | 35 | 37 | 20 | 17 | 18 |
| Container No. | V7 | V9 | V10 | V3 | V6 | V8 |
| Wt. Sample Wet + Tare | 87.10 | 99.39 | 87.97 | 76.66 | 96.46 | 83.09 |
| Wt. Sample Dry + Tare | 82.01 | 93.80 | 82.73 | 72.96 | 90.66 | 77.19 |
| Wt. Water | 5.09 | 5.59 | 5.24 | 3.70 | 5.80 | 5.90 |
| Tare Container | 69.16 | 79.58 | 69.43 | 64.10 | 76.78 | 62.91 |
| Wt. of Dry Soil | 12.85 | 14.22 | 13.30 | 8.86 | 13.88 | 14.28 |
| Moisture Content $w\%$ | 39.6 | 39.3 | 39.4 | 41.7 | 41.8 | 41.4 |




**Average Values**

$w_l$ = 40.6

$w_p$ = 35.8

$w_s$ = _____

$I_p$ = 4.8

$I_f$ = _____

$I_t$ = _____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AD | AM | AC |
| Wt. Sample Wet+Tare | 59.584 | 62.005 | 61.181 |
| Wt. Sample Dry+Tare | 57.673 | 59.687 | 59.190 |
| Wt. Water | 1.911 | 2.318 | 1.991 |
| Tare Container | 52.326 | 53.162 | 53.693 |
| Wt. of Dry Soil | 5.347 | 6.525 | 5.497 |
| Moisture Content % | 35.8 | 35.5 | 36.2 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w\%$ | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

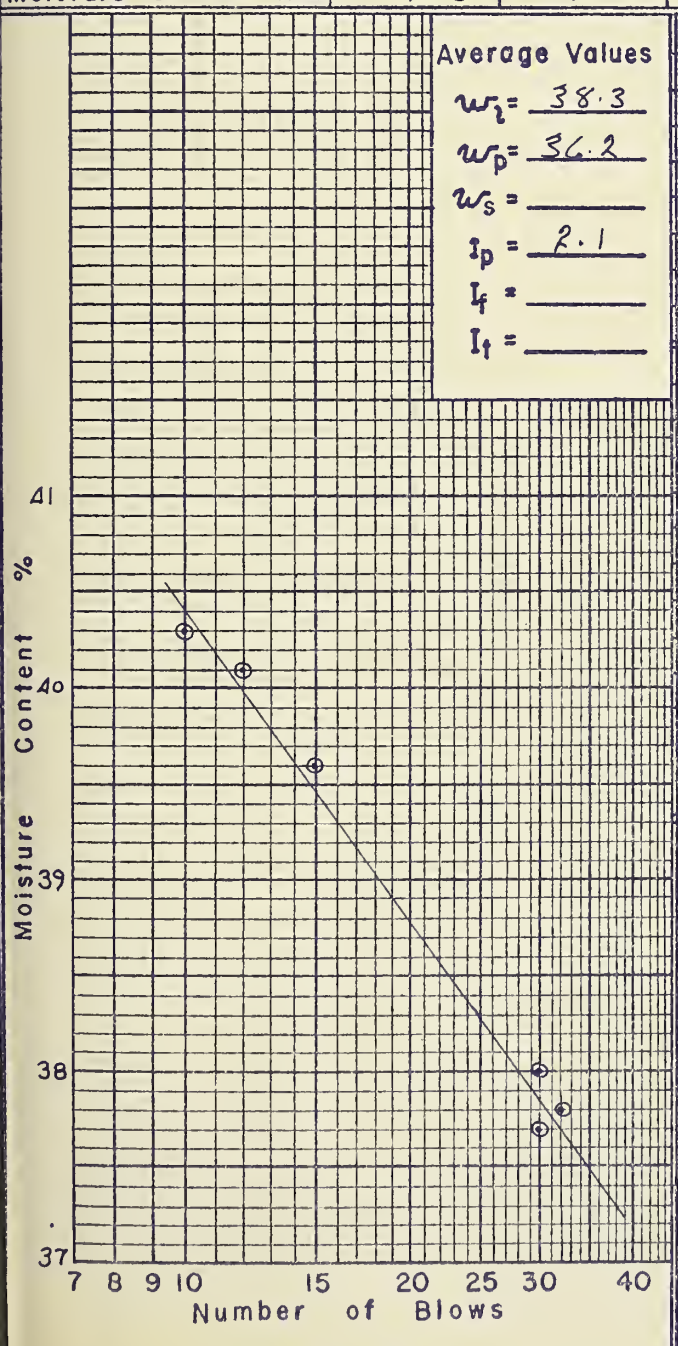
Remarks: Sample highly cemented and dry.

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 6
LOCATION
~~HOLE~~ Cycle # 3 ~~DEPTH~~ Day - 5
TECHNICIAN T.S.M. DATE 28-6-59

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 10 | 12 | 15 | 30 | 32 | 30 |
| Container No. | V90 | V72 | V83 | V66 | V42 | V45 |
| Wt. Sample Wet + Tare | 98.18 | 97.68 | 92.42 | 88.27 | 88.72 | 95.98 |
| Wt. Sample Dry + Tare | 90.89 | 89.75 | 86.39 | 82.25 | 82.87 | 88.78 |
| Wt. Water | 7.29 | 7.93 | 6.03 | 6.02 | 5.85 | 7.20 |
| Tare Container | 72.80 | 70.00 | 71.16 | 66.43 | 67.38 | 69.69 |
| Wt. of Dry Soil | 18.09 | 19.75 | 15.23 | 15.82 | 15.49 | 19.09 |
| Moisture Content w% | 40.3 | 40.1 | 39.6 | 38.0 | 37.8 | 37.7 |




Average Values
$w_l$ = 38.3
$w_p$ = 36.2
$w_s$ = ____
$I_p$ = 2.1
$I_f$ = ____
$I_t$ = ____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BE | AH | B-1 |
| Wt. Sample Wet+Tare | 63.142 | 58.153 | 64.231 |
| Wt. Sample Dry+Tare | 60.804 | 56.608 | 61.711 |
| Wt. Water | 2.338 | 1.545 | 2.520 |
| Tare Container | 54.381 | 52.057 | 54.734 |
| Wt. of Dry Soil | 6.423 | 4.551 | 6.977 |
| Moisture Content % | 36.3 | 34.0 | 36.1 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content w% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

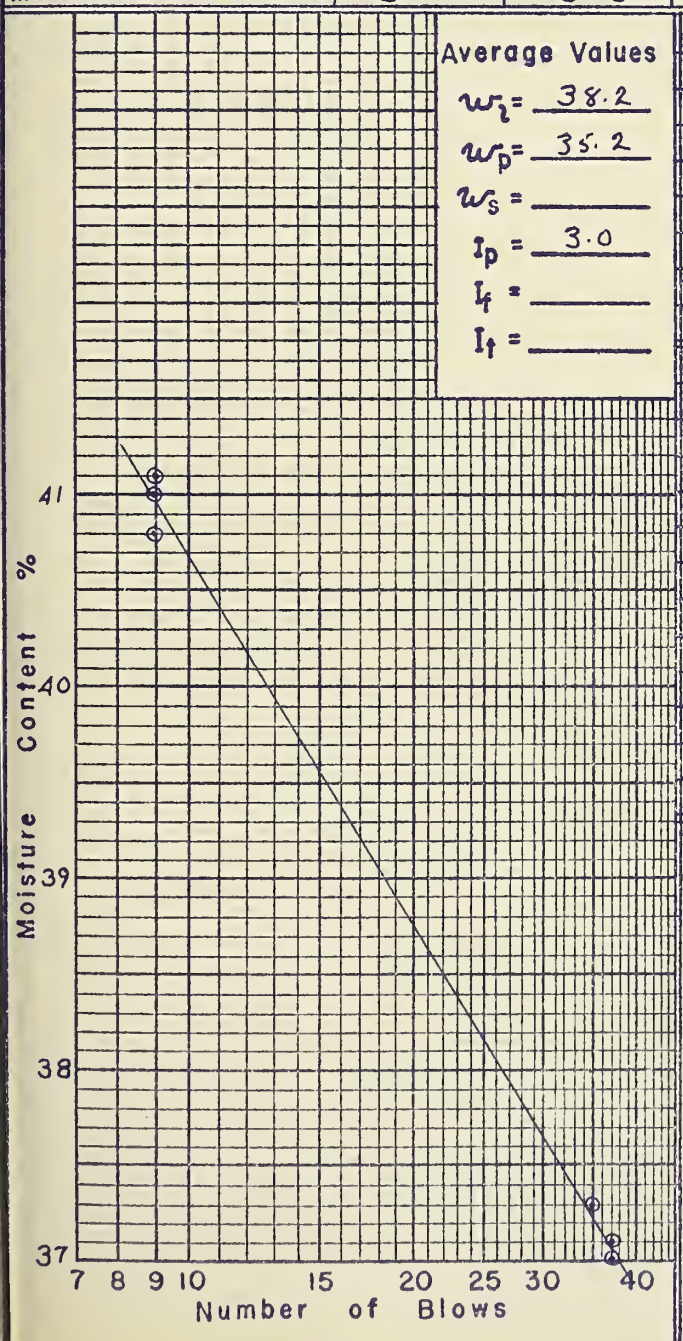
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 6
LOCATION
[redacted] Cycle # 12 [redacted] Day 14
TECHNICIAN IS-1 DATE 7-7-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 37 | 35 | 37 | 9 | 9 | 9 |
| Container No. | V62 | V71 | V86 | V77 | V70 | V52 |
| Wt. Sample Wet + Tare | 88.79 | 97.79 | 102.11 | 103.90 | 106.73 | 98.93 |
| Wt. Sample Dry + Tare | 82.36 | 91.50 | 94.93 | 95.42 | 99.59 | 91.94 |
| Wt. Water | 6.43 | 6.29 | 7.18 | 8.48 | 7.14 | 6.99 |
| Tare Container | 65.05 | 74.63 | 75.50 | 74.80 | 82.18 | 74.82 |
| Wt. of Dry Soil | 17.31 | 16.87 | 19.43 | 20.62 | 17.41 | 17.12 |
| Moisture Content $w$% | 37.1 | 37.3 | 37.0 | 41.1 | 41.0 | 40.8 |




Average Values
$w_l$ = 38.2
$w_p$ = 35.2
$w_s$ = ____
$I_p$ = 3.0
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | VA | BW | AF |
| Wt. Sample Wet+Tare | 60.200 | 59.927 | 58.924 |
| Wt. Sample Dry+Tare | 58.638 | 58.577 | 57.441 |
| Wt. Water | 1.562 | 1.350 | 1.483 |
| Tare Container | 54.431 | 54.734 | 53.395 |
| Wt. of Dry Soil | 4.207 | 3.843 | 4.046 |
| Moisture Content % | 37.2 | 35.1 | 36.7 |

## Plastic ~~Shrinkage~~ Limit

| Trial No. | A | 5 | |
|---|---|---|---|
| Container No. | BI | BT | |
| Wt. Sample Wet + Tare | 60.671 | 60.011 | |
| Wt. Sample Dry + Tare | 59.235 | 58.254 | Dry. |
| Wt. Water | 1.436 | 1.757 | |
| Tare Container | 54.942 | 53.062 | |
| Wt. of Dry Soil $W_o$ | 4.293 | 5.192 | |
| Moisture Content $w$% | 33.4 | 33.8 | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

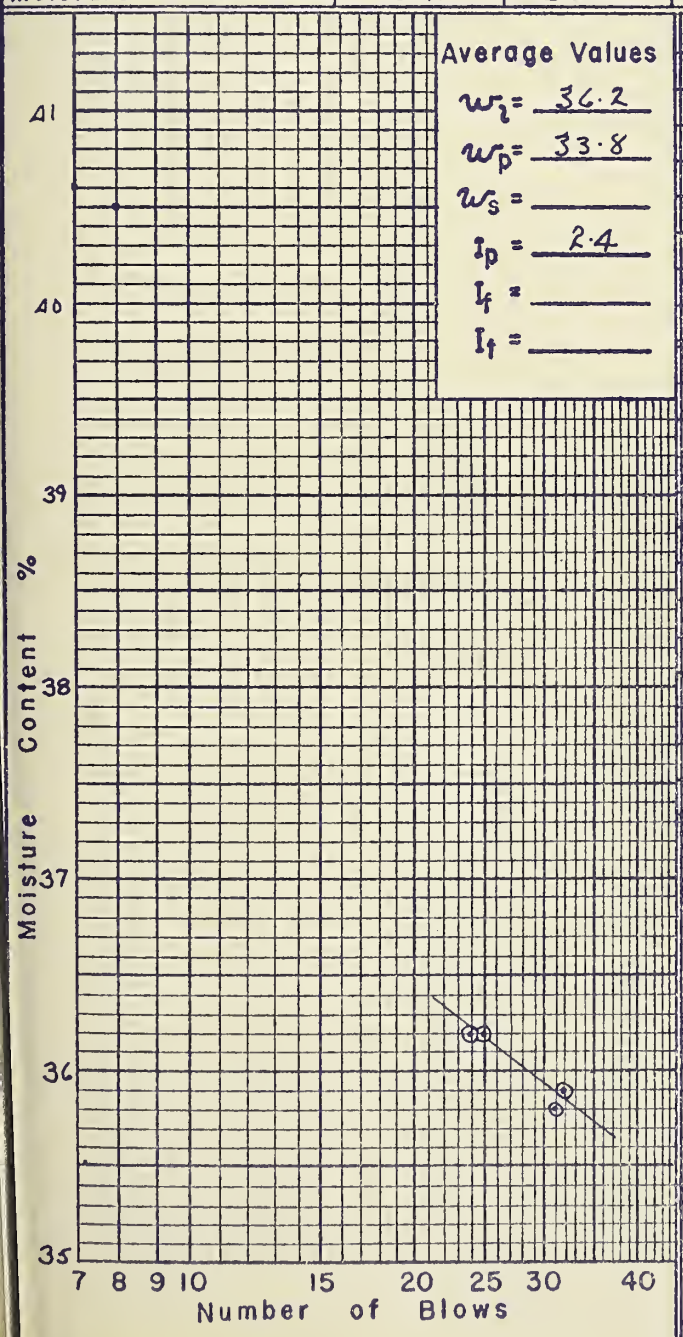
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 6
LOCATION
[redacted] Cycle # 25 [redacted]
TECHNICIAN T.S.L. DATE 23-7-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 25 | 24 | 31 | 32 | 7 | 8 |
| Container No. | VAT | VG7 | VG6 | V86 | VG2 | VAC |
| Wt. Sample Wet + Tare | 85.75 | 95.27 | 96.96 | 102.20 | 92.47 | 117.61 |
| Wt. Sample Dry + Tare | 79.97 | 88.26 | 88.92 | 95.14 | 84.55 | 107.85 |
| Wt. Water | 5.78 | 7.01 | 8.04 | 7.06 | 7.92 | 9.76 |
| Tare Container | 64.00 | 68.91 | 66.43 | 75.80 | 65.05 | 83.71 |
| Wt. of Dry Soil | 15.97 | 19.35 | 22.49 | 19.64 | 19.50 | 24.14 |
| Moisture Content w% | 36.2 | 36.2 | 35.8 | 35.9 | 40.6 | 40.5 |




Average Values
$w_l$ = 36.2
$w_p$ = 33.8
$w_s$ = ____
$I_p$ = 2.4
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BT | AP | BE |
| Wt. Sample Wet+Tare | 60.014 | 60.005 | 59.908 |
| Wt. Sample Dry+Tare | 58.231 | 58.321 | 58.536 |
| Wt. Water | 1.783 | 1.684 | 1.372 |
| Tare Container | 53.062 | 53.395 | 54.381 |
| Wt. of Dry Soil | 5.169 | 4.926 | 4.855 |
| Moisture Content % | 34.3 | 34.2 | 33.0 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content w% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

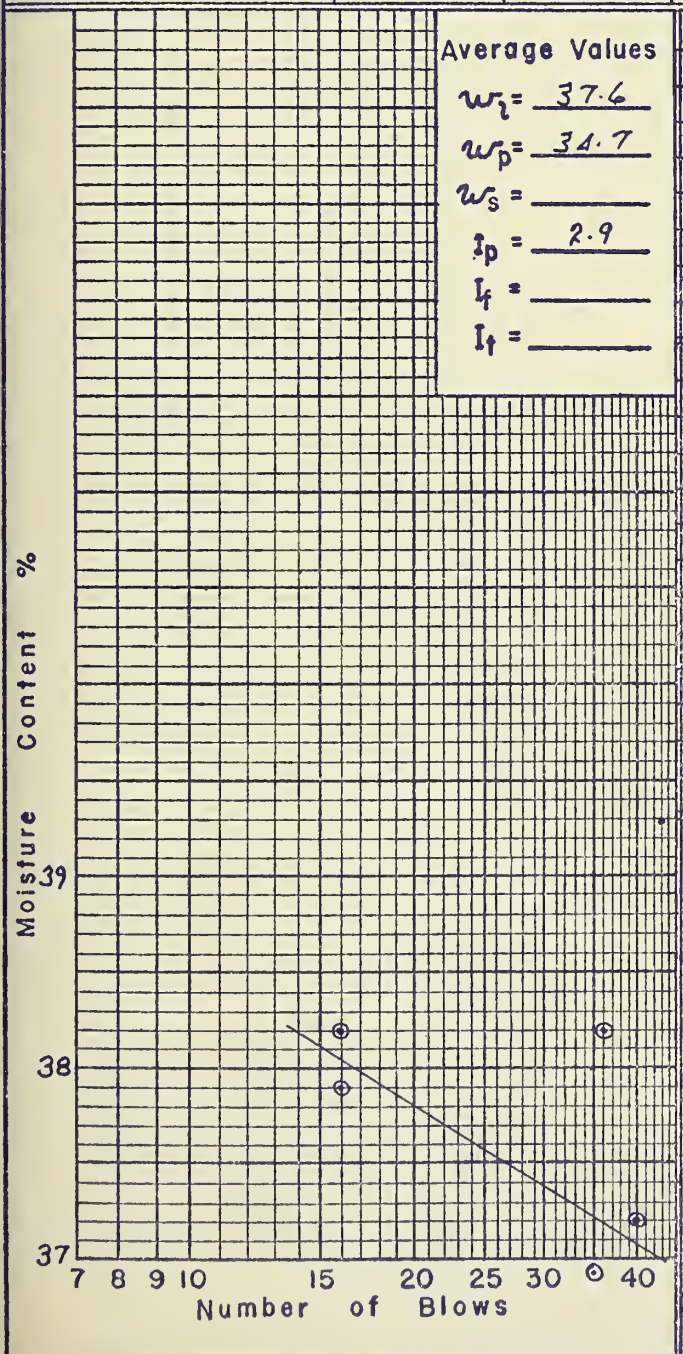
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest. |
| SITE | Crawford Pit |
| SAMPLE | # 6 |
| LOCATION | |
| ~~HOLE~~ | Cycle # 48 DEPTH |
| TECHNICIAN | DS DATE 17-8-59 |

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 16 | 16 | 16 | 35 | 40 | 36 |
| Container No. | V50 | V62 | V57 | V86 | V67 | V47 |
| Wt. Sample Wet + Tare | 108.59 | 92.96 | 96.81 | 97.14 | 92.20 | 87.50 |
| Wt. Sample Dry + Tare | 101.11 | 85.25 | 89.69 | 91.30 | 85.88 | 81.00 |
| Wt. Water | 7.48 | 7.71 | 7.12 | 5.84 | 6.32 | 6.50 |
| Tare Container | 81.54 | 65.05 | 70.91 | 75.50 | 68.91 | 64.00 |
| Wt. of Dry Soil | 19.57 | 20.20 | 18.78 | 15.80 | 16.97 | 17.00 |
| Moisture Content $w$% | 38.2 | 38.2 | 37.9 | 36.9 | 37.2 | 38.2 |




**Average Values**

$w_l$ = 37.6

$w_p$ = 34.7

$w_s$ = _____

$I_p$ = 2.9

$I_f$ = _____

$I_t$ = _____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AE | AT | AD |
| Wt. Sample Wet+Tare | 56.430 | 58.728 | 55.564 |
| Wt. Sample Dry+Tare | 55.562 | 57.427 | 54.734 |
| Wt. Water | 0.868 | 1.301 | 0.830 |
| Tare Container | 53.087 | 53.715 | 52.326 |
| Wt. of Dry Soil | 2.475 | 3.712 | 2.408 |
| Moisture Content % | 34.7 | 35.0 | 34.5 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

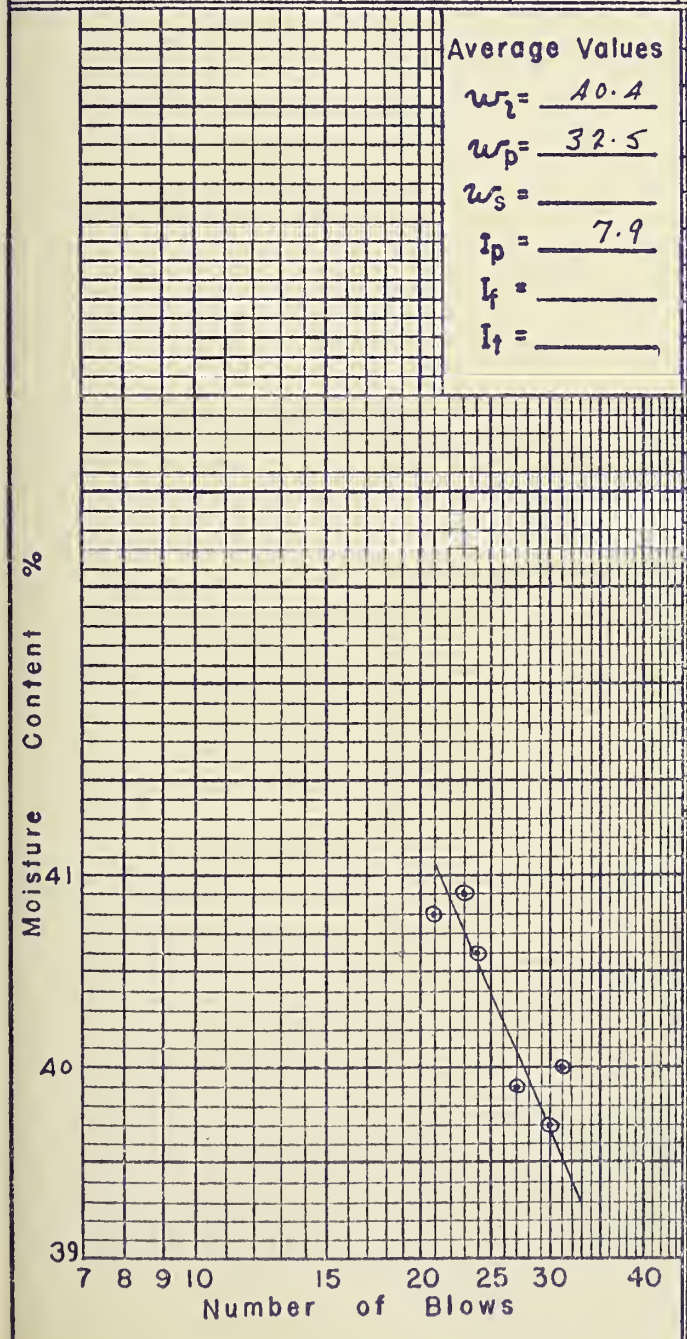
Remarks: _____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE #7
LOCATION
~~HOLE~~ Cycle # 1 ~~DEPTH~~ Day #4
TECHNICIAN I.S.L. DATE 25-6-59

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 23 | 21 | 24 | 27 | 31 | 30 |
| Container No. | V64 | V66 | V67 | V65 | V86 | V63 |
| Wt. Sample Wet + Tare | 89.02 | 92.32 | 92.25 | 90.21 | 92.30 | 88.12 |
| Wt. Sample Dry + Tare | 82.57 | 84.82 | 85.50 | 83.84 | 87.50 | 82.35 |
| Wt. Water | 6.45 | 7.50 | 6.75 | 6.37 | 4.80 | 5.77 |
| Tare Container | 66.80 | 66.43 | 68.91 | 67.88 | 75.50 | 67.80 |
| Wt. of Dry Soil | 15.77 | 18.39 | 16.59 | 15.96 | 12.00 | 14.55 |
| Moisture Content $w$% | 40.9 | 40.8 | 40.6 | 39.9 | 40.0 | 39.7 |




**Average Values**

$w_l$ = 40.4
$w_p$ = 32.5
$w_s$ = _____
$I_p$ = 7.9
$I_f$ = _____
$I_t$ = _____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AT | AS | AP |
| Wt. Sample Wet+Tare | 64.333 | 64.023 | 65.353 |
| Wt. Sample Dry+Tare | 61.737 | 61.601 | 62.426 |
| Wt. Water | 2.596 | 2.422 | 2.927 |
| Tare Container | 53.715 | 54.249 | 53.395 |
| Wt. of Dry Soil | 8.022 | 7.352 | 9.031 |
| Moisture Content % | 32.3 | 32.9 | 32.4 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

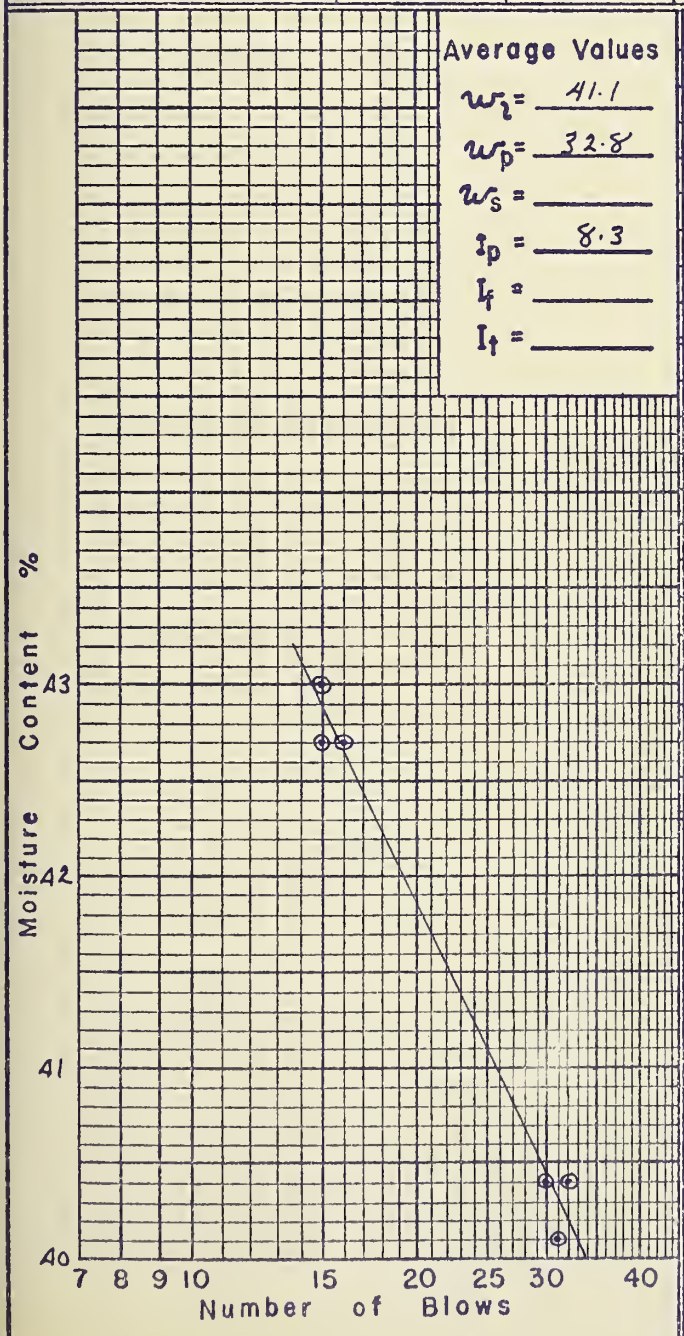
Remarks: _____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit.
SAMPLE # 7
LOCATION
~~HOLE~~ Cycle # 3 DEPTH Day 4
TECHNICIAN T.S.L. DATE 27-6-59

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 15 | 16 | 15 | 30 | 32 | 31 |
| Container No. | V74 | V58 | V65 | V10 | V69 | V70 |
| Wt. Sample Wet + Tare | 94.57 | 89.04 | 90.13 | 90.23 | 89.64 | 106.97 |
| Wt. Sample Dry + Tare | 87.51 | 83.23 | 83.47 | 84.25 | 83.84 | 99.88 |
| Wt. Water | 7.06 | 5.81 | 6.66 | 5.98 | 5.80 | 7.09 |
| Tare Container | 71.11 | 69.63 | 67.88 | 69.43 | 69.41 | 82.18 |
| Wt. of Dry Soil | 16.40 | 13.60 | 15.59 | 14.82 | 14.43 | 17.70 |
| Moisture Content $w\%$ | 43.0 | 42.7 | 42.7 | 40.4 | 40.4 | 40.1 |




**Average Values**

$w_l$ = 41.1
$w_p$ = 32.8
$w_s$ = ____
$I_p$ = 8.3
$I_f$ = ____
$I_t$ = ____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BW | BE | AS |
| Wt. Sample Wet+Tare | 62.611 | 63.240 | 60.834 |
| Wt. Sample Dry+Tare | 60.655 | 61.106 | 59.209 |
| Wt. Water | 1.956 | 2.134 | 1.625 |
| Tare Container | 54.734 | 54.381 | 54.249 |
| Wt. of Dry Soil | 5.921 | 6.725 | 4.960 |
| Moisture Content % | 33.0 | 31.7 | 32.7 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w\%$ | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

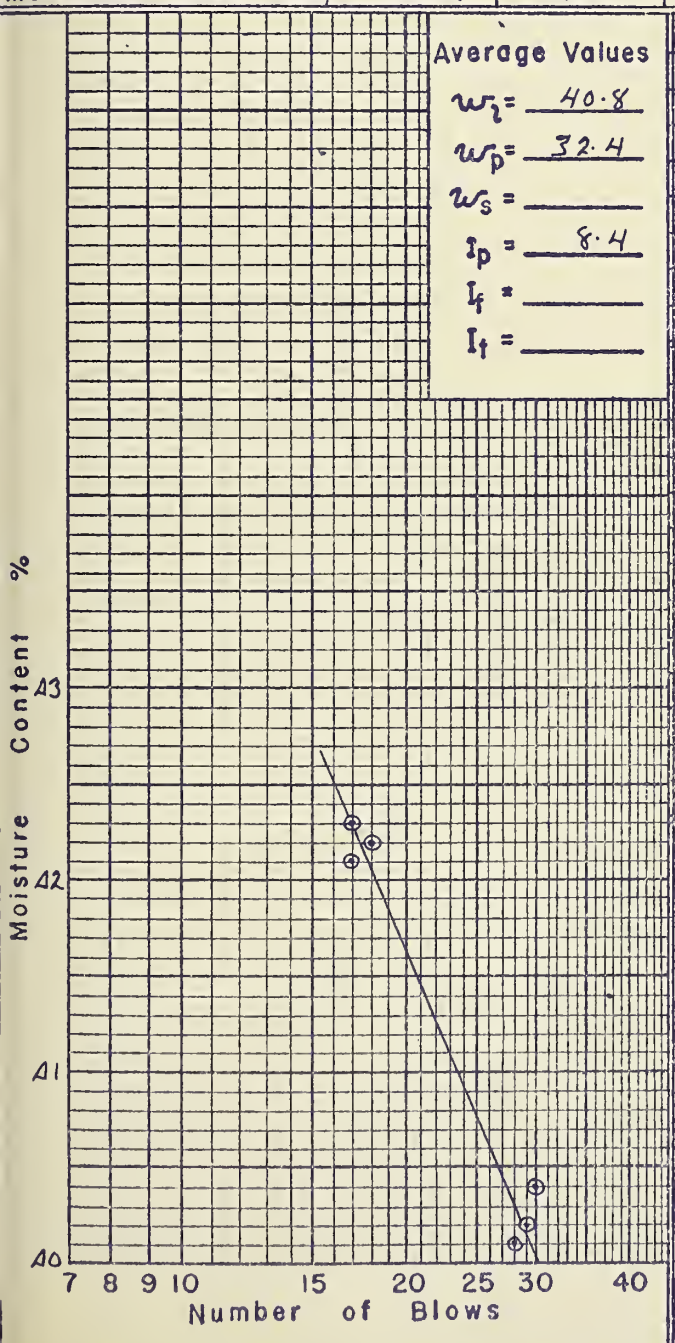
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 7
LOCATION
~~HOLE~~ Cycle #12 ~~DEPTH~~ Day 13
TECHNICIAN TSL DATE 6-7-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 30 | 28 | 29 | 18 | 17 | 17 |
| Container No. | V71 | V70 | V77 | V52 | V62 | V86 |
| Wt. Sample Wet + Tare | 92.48 | 104.43 | 101.45 | 97.64 | 91.47 | 104.51 |
| Wt. Sample Dry + Tare | 87.34 | 98.07 | 93.81 | 90.87 | 83.62 | 95.91 |
| Wt. Water | 5.14 | 6.36 | 7.64 | 6.77 | 7.85 | 8.60 |
| Tare Container | 74.63 | 82.18 | 74.80 | 74.82 | 65.05 | 75.50 |
| Wt. of Dry Soil | 12.71 | 15.89 | 19.01 | 16.05 | 18.57 | 20.41 |
| Moisture Content $w$% | 40.4 | 40.1 | 40.2 | 42.2 | 42.3 | 42.1 |




### Average Values

$w_l$ = 40.8
$w_p$ = 32.4
$w_s$ = ____
$I_p$ = 8.4
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AV | BI | AD |
| Wt. Sample Wet+Tare | 60.767 | 63.381 | 61.104 |
| Wt. Sample Dry+Tare | 59.229 | 61.279 | 58.976 |
| Wt. Water | 1.538 | 2.102 | 2.128 |
| Tare Container | 54.431 | 54.942 | 52.326 |
| Wt. of Dry Soil | 4.798 | 6.337 | 6.650 |
| Moisture Content % | 32.1 | 33.2 | 32.0 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

Remarks: ____

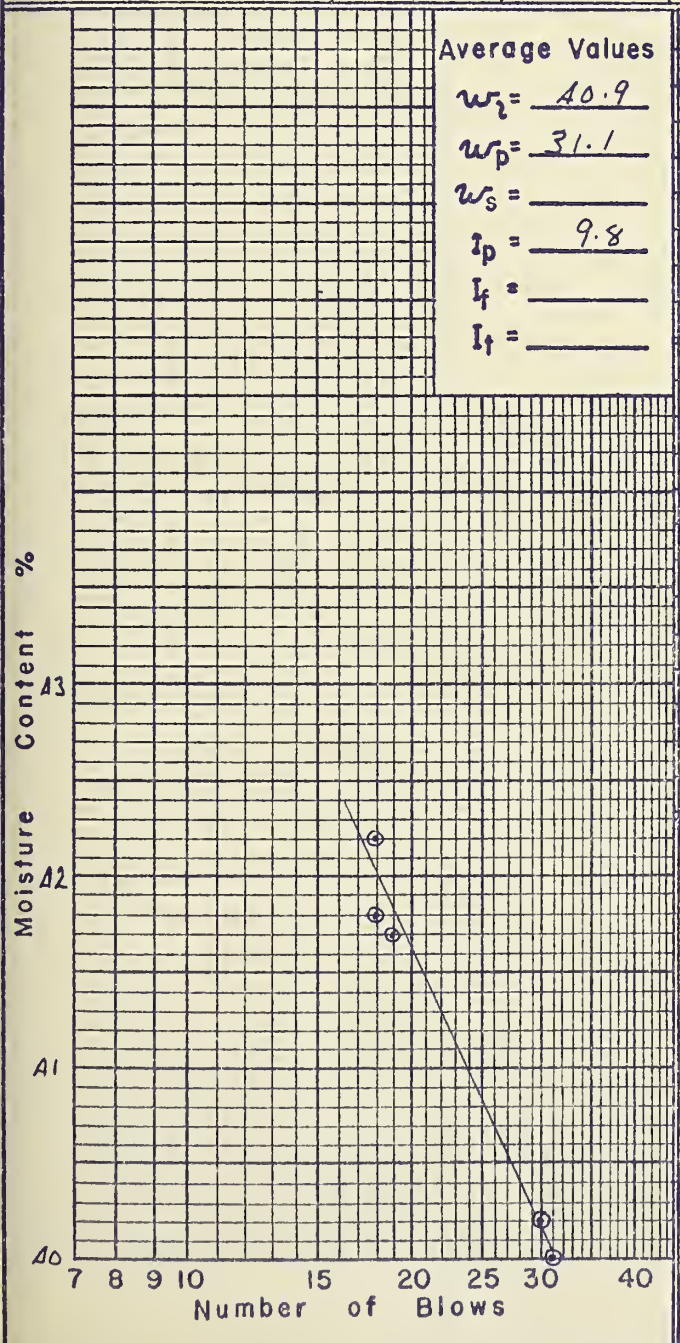
UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 7
LOCATION
~~HOLE~~ Cycle # 25 DEPTH Day 29
TECHNICIAN TSW DATE 22-7-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 30 | 30 | 31 | 18 | 18 | 19 |
| Container No. | V50 | V85 | V71 | V80 | V51 | V45 |
| Wt. Sample Wet + Tare | 104.46 | 103.18 | 99.20 | 101.02 | 93.52 | 101.27 |
| Wt. Sample Dry + Tare | 97.89 | 96.65 | 92.19 | 92.41 | 85.44 | 91.96 |
| Wt. Water | 6.57 | 6.53 | 7.01 | 8.61 | 8.08 | 9.31 |
| Tare Container | 81.54 | 80.42 | 74.63 | 72.00 | 66.13 | 69.69 |
| Wt. of Dry Soil | 16.35 | 16.23 | 17.56 | 20.41 | 19.31 | 22.27 |
| Moisture Content $w$% | 40.2 | 40.2 | 40.0 | 42.2 | 41.8 | 41.7 |




Average Values
$w_L$ = 40.9
$w_P$ = 31.1
$w_S$ = ____
$I_P$ = 9.8
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BT | AE | BL |
| Wt. Sample Wet + Tare | 56.807 | 58.179 | 59.741 |
| Wt. Sample Dry + Tare | 55.925 | 56.960 | 58.555 |
| Wt. Water | 0.882 | 1.219 | 1.186 |
| Tare Container | 53.062 | 53.087 | 54.741 |
| Wt. of Dry Soil | 2.863 | 3.873 | 3.814 |
| Moisture Content % | 30.8 | 31.5 | 31.1 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V - V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V - V_o}{W_o} \times 100\right)$$

Description of Sample: ____

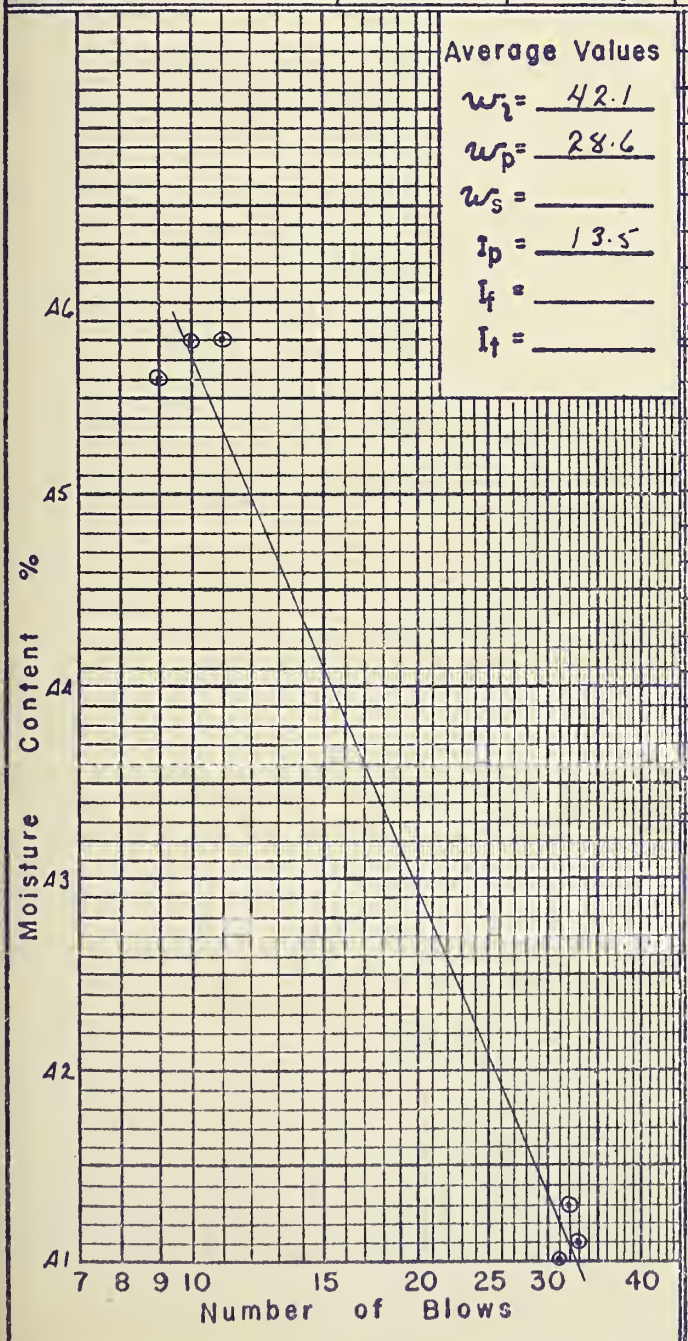
Remarks: Sample lighter in color than corresponding F.T. sample #1. Smooth fat plastic texture.

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Freeze-Thaw Invest.
SITE Crawford Pit
SAMPLE # 7
LOCATION
~~HOLE~~ Cycle # 48 DEPTH
TECHNICIAN D.S. DATE 15-8-59

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 9 | 11 | 10 | 33 | 32 | 31 |
| Container No. | V73 | V6 | V7 | V57 | V72 | V42 |
| Wt. Sample Wet + Tare | 85.86 | 97.35 | 85.89 | 91.21 | 92.60 | 88.12 |
| Wt. Sample Dry + Tare | 79.72 | 90.89 | 80.64 | 85.30 | 86.00 | 82.09 |
| Wt. Water | 6.14 | 6.46 | 5.25 | 5.91 | 6.60 | 6.03 |
| Tare Container | 66.28 | 76.78 | 69.16 | 70.91 | 70.00 | 67.38 |
| Wt. of Dry Soil | 13.44 | 14.11 | 11.48 | 14.39 | 16.00 | 14.71 |
| Moisture Content $w$% | 45.6 | 45.8 | 45.8 | 41.1 | 41.3 | 41.0 |




Average Values
$w_l$ = 42.1
$w_p$ = 28.6
$w_s$ = ____
$I_p$ = 13.5
$I_f$ = ____
$I_t$ = ____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AV | AD | BA |
| Wt. Sample Wet+Tare | 65.078 | 61.390 | 60.986 |
| Wt. Sample Dry+Tare | 62.696 | 59.369 | 58.896 |
| Wt. Water | 2.382 | 2.021 | 2.090 |
| Tare Container | 54.431 | 52.326 | 51.756 |
| Wt. of Dry Soil | 8.265 | 7.043 | 7.143 |
| Moisture Content % | 28.8 | 28.8 | 28.2 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

Remarks: ____

UNIVERSITY of ALBERTA
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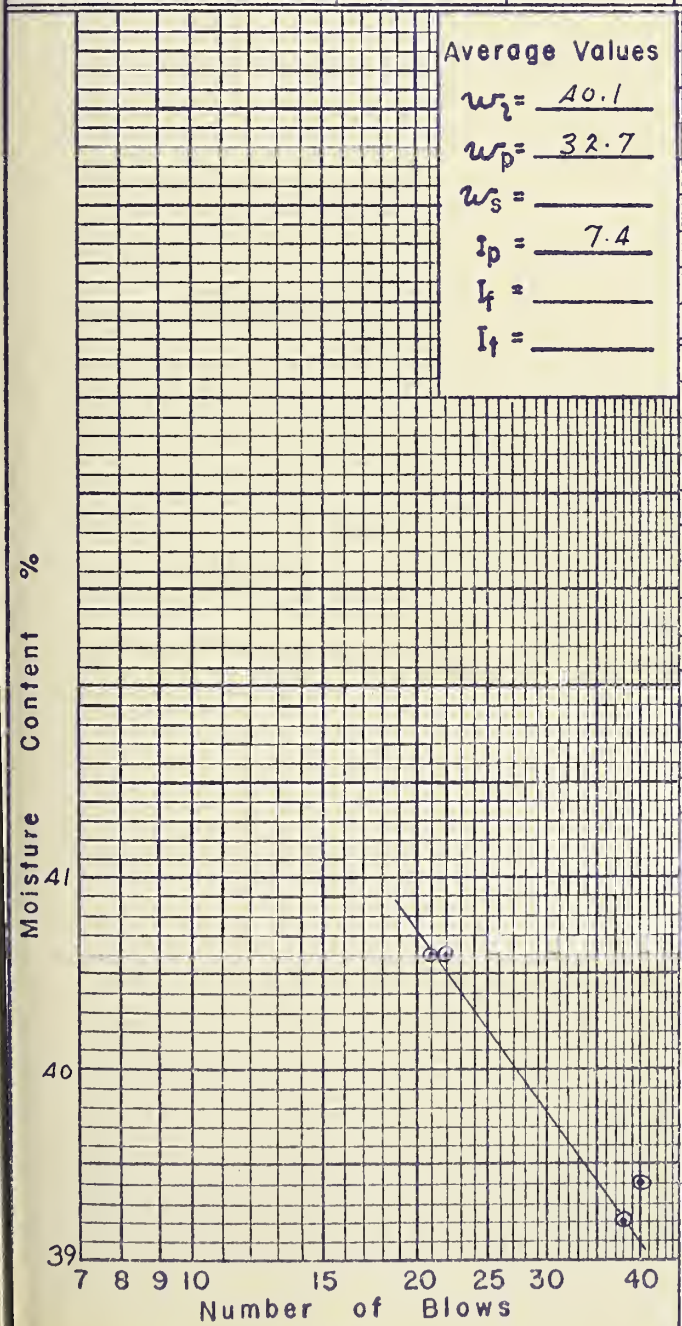
SOIL MECHANICS LABORATORY

# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 8
LOCATION
~~HOLE~~ Cycle # 1 DEPTH
TECHNICIAN DS DATE 25-6-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 21 | 21 | 20 | 34 | 33 | 33 |
| Container No. | V42 | V45 | V46 | V47 | V48 | V41 |
| Wt. Sample Wet + Tare | 82.36 | × 82.40 | 101.82 | 78.76 | 82.40 | 84.53 |
| Wt. Sample Dry + Tare | 78.03 | 86.03 | 96.60 | 74.59 | 78.71 | 81.13 |
| Wt. Water | 4.33 | — | 5.22 | 4.17 | 3.69 | 3.40 |
| Tare Container | 67.38 | 69.69 | 83.71 | 64.00 | 69.29 | 72.47 |
| Wt. of Dry Soil | 10.65 | 6.34 | 12.89 | 10.59 | 9.42 | 8.66 |
| Moisture Content w% | 40.6 | — | 40.6 | 39.4 | 39.2 | 39.2 |




Average Values
$w_l$ = 40.1
$w_p$ = 32.7
$w_s$ = ____
$I_p$ = 7.4
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | 22 | BL | BI |
| Wt. Sample Wet+Tare | 43.330 | 60.539 | 65.239 |
| Wt. Sample Dry+Tare | 41.458 | 59.115 | 62.693 |
| Wt. Water | 1.872 | 1.424 | 2.546 |
| Tare Container | 35.747 | 54.741 | 54.942 |
| Wt. of Dry Soil | 5.711 | 4.374 | 7.751 |
| Moisture Content % | 32.8 | 32.6 | 32.8 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content w% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

Remarks: Error in wet wt. of Trial # 2.

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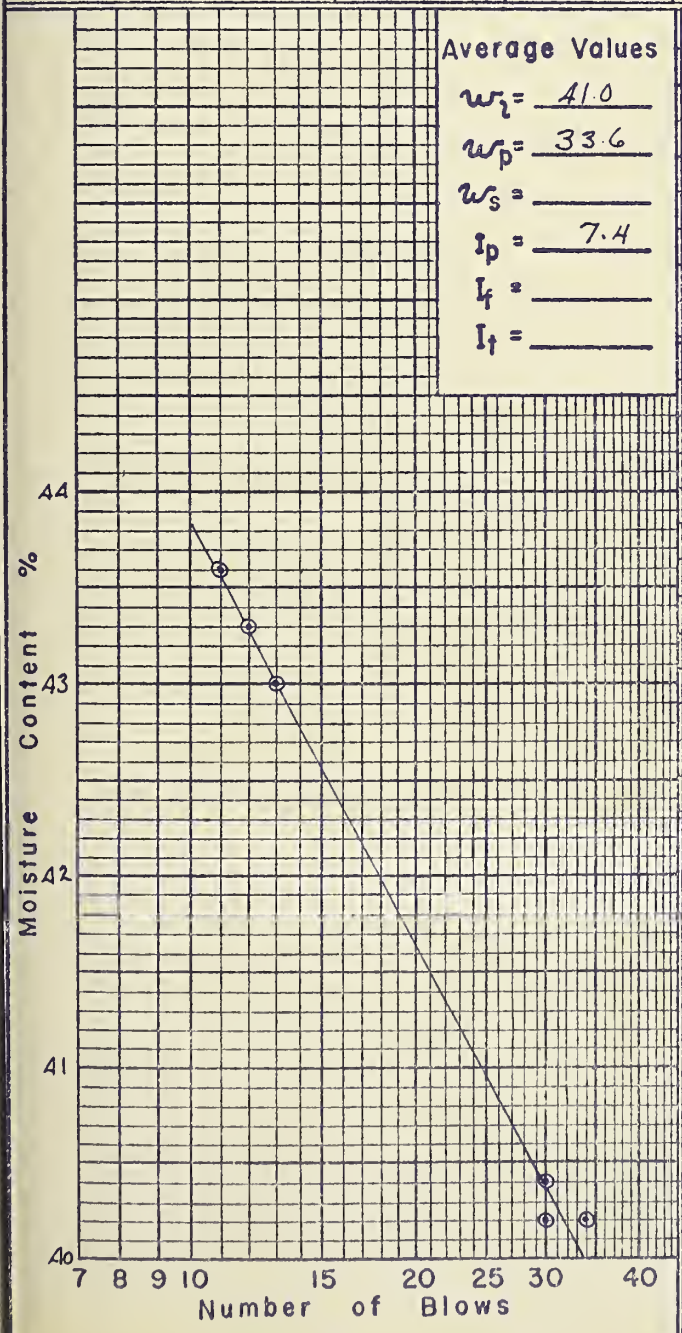
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 8
LOCATION
NOTE Cycle # 3 DEPTH
TECHNICIAN D.S. DATE 27-6-59

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 13 | 12 | 11 | 30 | 30 | 34 |
| Container No. | V83 | V72 | V63 | VA2 | V90 | V51 |
| Wt. Sample Wet + Tare | 83.90 | 82.04 | 82.60 | 83.01 | 87.04 | 77.29 |
| Wt. Sample Dry + Tare | 80.07 | 78.40 | 78.11 | 78.53 | 82.94 | 74.09 |
| Wt. Water | 3.83 | 3.64 | 4.49 | 4.48 | 4.10 | 3.20 |
| Tare Container | 71.16 | 70.00 | 67.80 | 67.38 | 72.80 | 66.13 |
| Wt. of Dry Soil | 8.91 | 8.40 | 10.31 | 11.15 | 10.14 | 7.96 |
| Moisture Content $w$% | 43.0 | 43.3 | 43.6 | 40.2 | 40.4 | 40.2 |




**Average Values**

$w_l$ = 41.0
$w_p$ = 33.6
$w_s$ = ____
$I_p$ = 7.4
$I_f$ = ____
$I_t$ = ____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AM | BK | AV |
| Wt. Sample Wet+Tare | 61.080 | 62.295 | 59.970 |
| Wt. Sample Dry+Tare | 59.059 | 60.014 | 58.583 |
| Wt. Water | 2.021 | 2.281 | 1.387 |
| Tare Container | 53.162 | 53.262 | 54.431 |
| Wt. of Dry Soil | 5.897 | 6.852 | 4.152 |
| Moisture Content % | 34.3 | 33.3 | 33.3 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

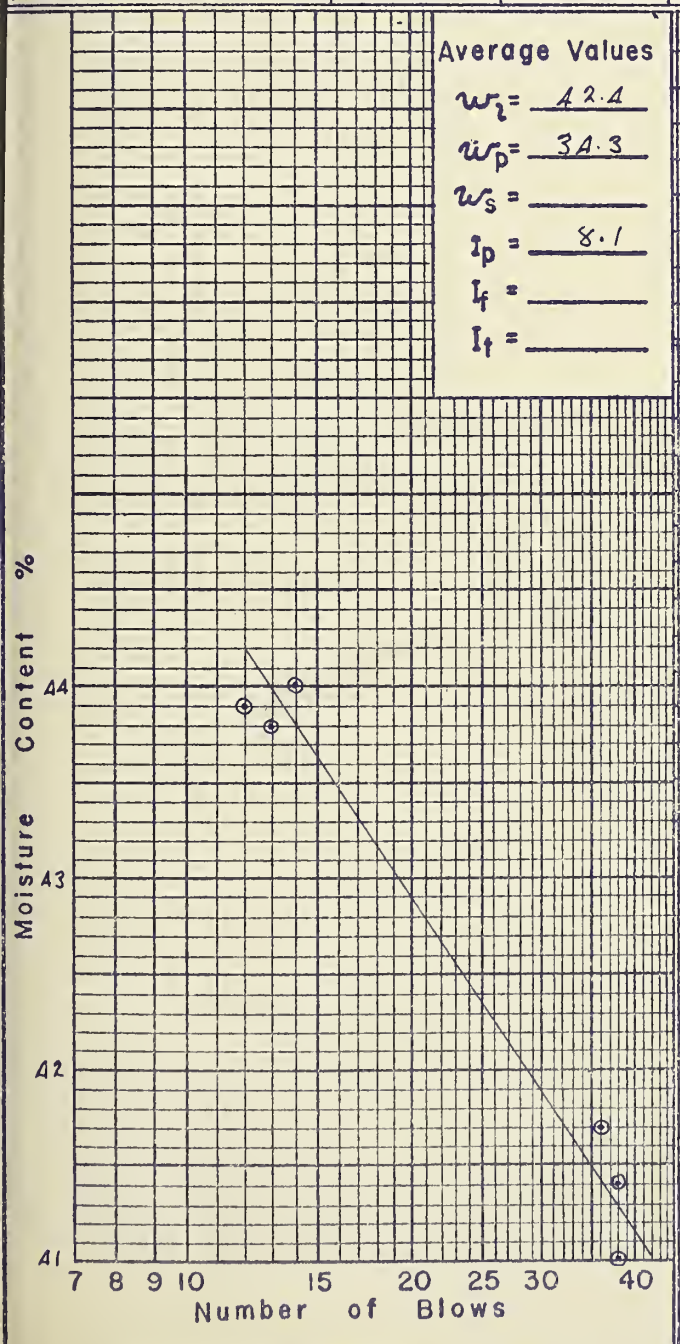
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest. |
| SITE | Crawford Pit |
| SAMPLE | # 8 |
| LOCATION | |
| ~~HOLE~~ | Cycle # 12 DEPTH |
| TECHNICIAN | D.S. DATE 6-7-59 |

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 14 | 12 | 13 | 36 | 38 | 38 |
| Container No. | V63 | V24 | V90 | V84 | V85 | V58 |
| Wt. Sample Wet + Tare | 82.60 | 91.36 | 88.20 | 87.90 | 94.67 | 84.79 |
| Wt. Sample Dry + Tare | 78.08 | 87.25 | 83.51 | 84.22 | 90.50 | 80.38 |
| Wt. Water | 4.52 | 4.11 | 4.69 | 3.68 | 4.17 | 4.41 |
| Tare Container | 67.80 | 77.90 | 72.80 | 75.38 | 80.42 | 69.63 |
| Wt. of Dry Soil | 10.28 | 9.35 | 10.71 | 8.84 | 10.08 | 10.75 |
| Moisture Content $w$% | 44.0 | 43.9 | 43.8 | 41.7 | 41.4 | 41.0 |




**Average Values**

$w_l$ = 42.4

$w_p$ = 34.3

$w_s$ = _____

$I_p$ = 8.1

$I_f$ = _____

$I_t$ = _____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AT | 22 | 28 |
| Wt. Sample Wet + Tare | 63.806 | 47.517 | 47.624 |
| Wt. Sample Dry + Tare | 61.220 | 44.527 | 44.669 |
| Wt. Water | 2.586 | 2.990 | 2.955 |
| Tare Container | 53.715 | 35.747 | 36.030 |
| Wt. of Dry Soil | 7.505 | 8.780 | 8.639 |
| Moisture Content % | 34.5 | 34.1 | 34.2 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V - V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V - V_o}{W_o} \times 100\right)$$

Description of Sample: _____

Remarks: _____

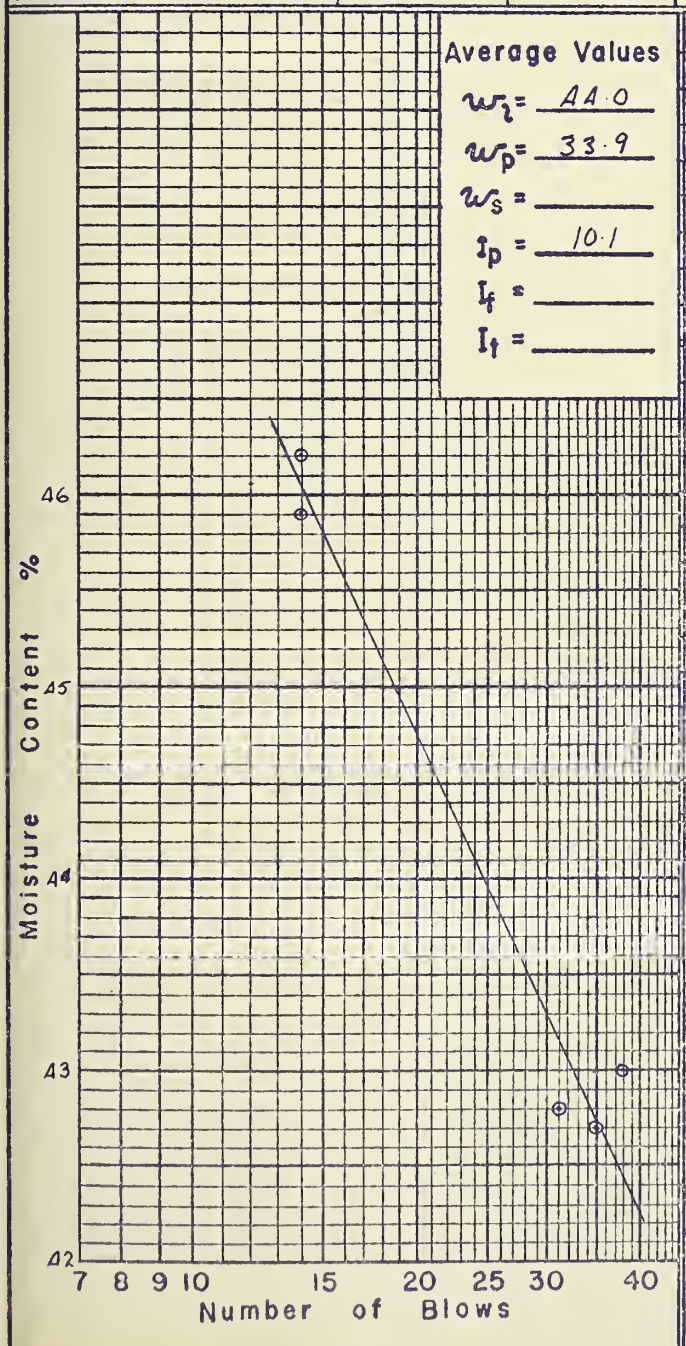
# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Freeze Thaw Invest
SITE Crawford Pit
SAMPLE # 8
LOCATION
~~HOLE~~ Cycle # 25 DEPTH
TECHNICIAN D.S DATE 22-7-59

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 14 | 14 | 14 | 31 | 35 | 38 |
| Container No. | V48 | V81 | V63 | V7 | V72 | V61 |
| Wt. Sample Wet + Tare | 89.51 | 95.69 | 87.32 | 90.04 | 89.41 | 96.80 |
| Wt. Sample Dry + Tare | 83.15 | 89.52 | 81.18 | 83.78 | 83.60 | 90.76 |
| Wt. Water | 6.36 | 6.17 | 6.14 | 6.26 | 5.81 | 6.04 |
| Tare Container | 69.29 | 76.19 | 67.80 | 69.16 | 70.00 | 76.70 |
| Wt. of Dry Soil | 13.86 | 13.38 | 13.38 | 14.62 | 13.60 | 14.06 |
| Moisture Content $w$% | 45.9 | 46.2 | 45.9 | 42.8 | 42.7 | 43.0 |

Average Values
$w_l$ = 44.0
$w_p$ = 33.9
$w_s$ = _____
$I_p$ = 10.1
$I_f$ = _____
$I_t$ = _____




### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | 1 | 2 | 3 |
| Wt. Sample Wet+Tare | 41.820 | 44.405 | 43.510 |
| Wt. Sample Dry+Tare | 40.230 | 42.306 | 41.418 |
| Wt. Water | 1.590 | 2.099 | 2.092 |
| Tare Container | 35.680 | 36.010 | 35.190 |
| Wt. of Dry Soil | 4.550 | 6.296 | 6.228 |
| Moisture Content % | 34.9 | 33.4 | 36.6 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

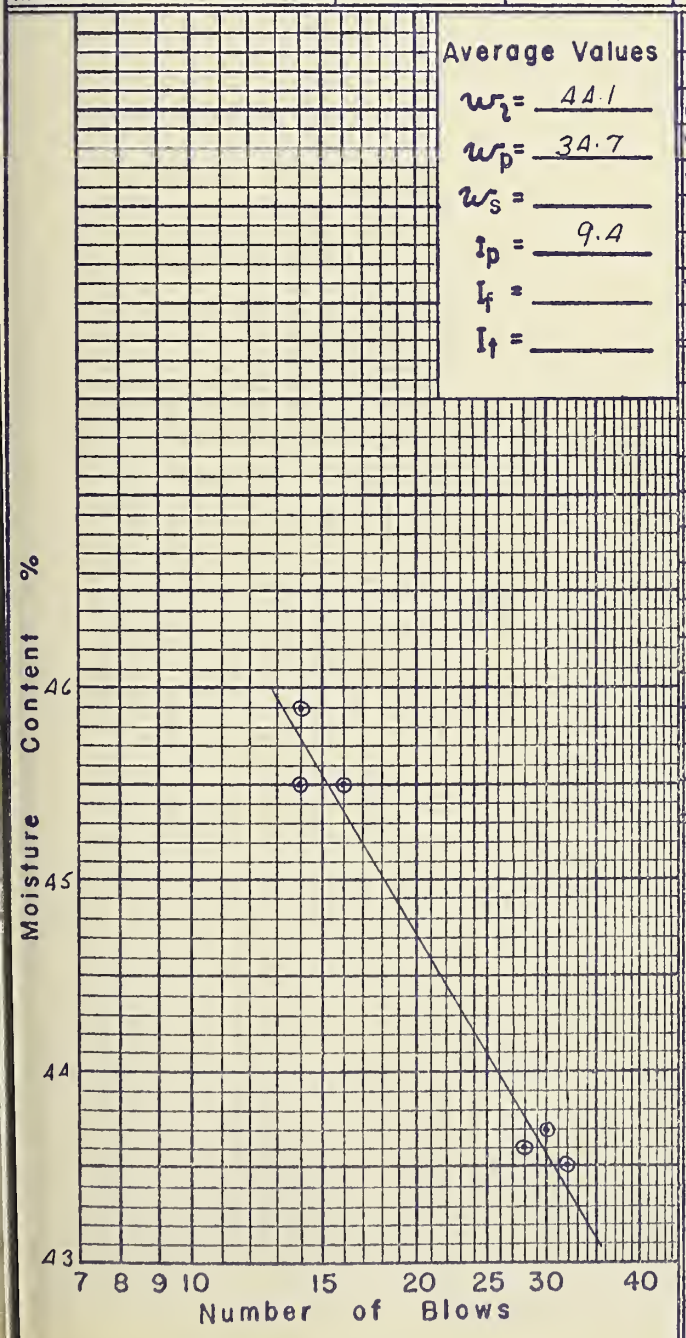
Remarks: _____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest. |
| SITE | Crawford Pit |
| SAMPLE | # 8 |
| LOCATION | |
| HOLE | Cycle # 48 DEPTH |
| TECHNICIAN | DS DATE 15-8-59 |

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 14 | 16 | 14 | 28 | 30 | 32 |
| Container No. | V90 | V61 | V81 | V9 | V84 | V69 |
| Wt. Sample Wet + Tare | 93.92 | 95.50 | 97.80 | 103.90 | 97.30 | 90.34 |
| Wt. Sample Dry + Tare | 87.31 | 89.61 | 91.00 | 96.51 | 90.63 | 84.00 |
| Wt. Water | 6.61 | 5.89 | 6.80 | 7.39 | 6.67 | 6.34 |
| Tare Container | 72.80 | 76.70 | 76.19 | 79.58 | 75.38 | 69.41 |
| Wt. of Dry Soil | 14.51 | 12.91 | 14.81 | 16.93 | 15.25 | 14.59 |
| Moisture Content $w$% | 45.5 | 45.5 | 45.9 | 43.6 | 43.7 | 43.5 |




### Average Values

$w_l$ = 44.1

$w_p$ = 34.7

$w_s$ = _____

$I_p$ = 9.4

$I_f$ = _____

$I_t$ = _____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BL | AC | AT |
| Wt. Sample Wet+Tare | 62.096 | 63.959 | 63.231 |
| Wt. Sample Dry+Tare | 60.184 | 61.346 | 60.804 |
| Wt. Water | 1.912 | 2.613 | 2.427 |
| Tare Container | 54.741 | 53.639 | 53.715 |
| Wt. of Dry Soil | 5.443 | 8.707 | 7.089 |
| Moisture Content % | 35.2 | X30.0 | 34.3 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

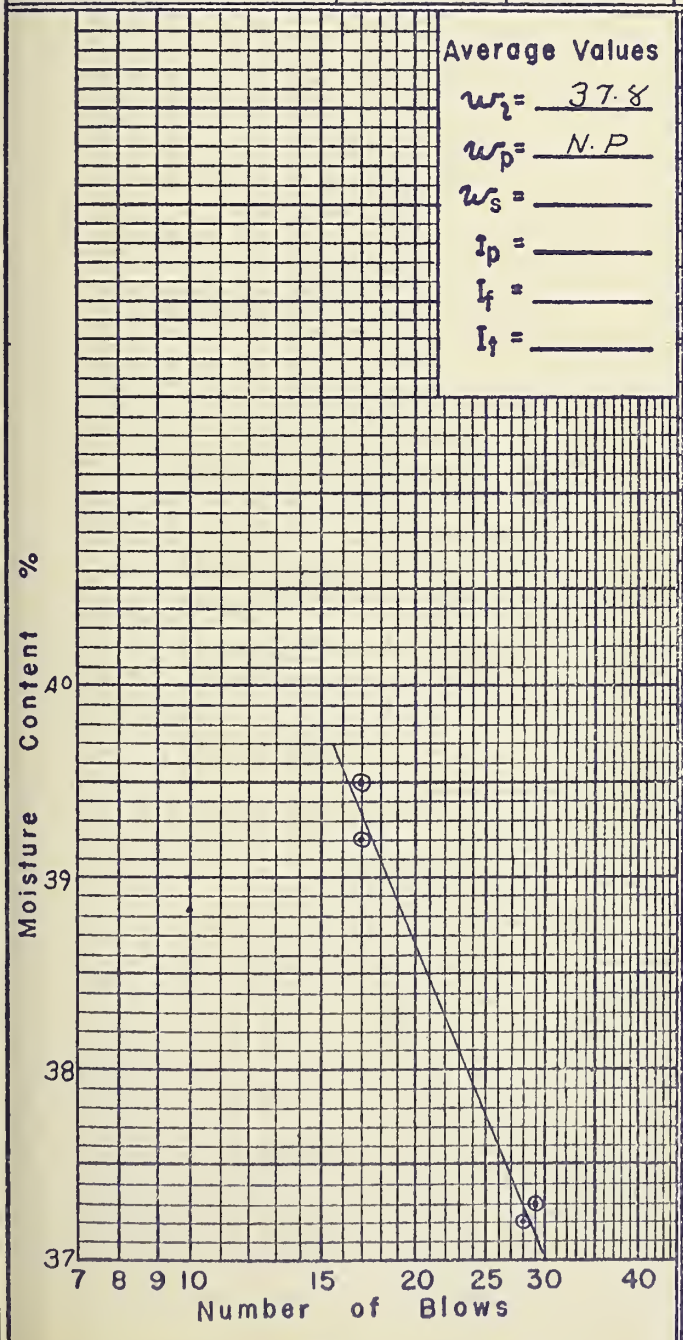
Remarks: Plastic Limit Trial # 2 assumed in error.

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest. |
| SITE | Crawford Pit |
| SAMPLE | # 9 |
| LOCATION | |
| ~~HOLE~~ | Cycle # 1 DEPTH Day 2 |
| TECHNICIAN | TSW DATE 25-6-59 |

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | | |
|---|---|---|---|---|---|---|
| No. of Blows | 28 | 29 | 17 | 17 | | |
| Container No. | Y68 | Y69 | Y70 | Y71 | | |
| Wt. Sample Wet + Tare | 105.60 | 91.52 | 102.06 | 100.28 | | |
| Wt. Sample Dry + Tare | 100.59 | 85.51 | 96.46 | 93.02 | | |
| Wt. Water | 5.01 | 6.01 | 5.60 | 7.26 | | |
| Tare Container | 87.13 | 69.41 | 82.18 | 74.63 | | |
| Wt. of Dry Soil | 13.46 | 16.10 | 14.28 | 18.39 | | |
| Moisture Content $w$% | 37.2 | 37.3 | 39.2 | 39.5 | | |




**Average Values**

$w_l$ = 37.8

$w_p$ = N.P

$w_s$ = _____

$I_p$ = _____

$I_f$ = _____

$I_t$ = _____

### Plastic Limit

| Trial No. | Non | Plastic | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet+Tare | | | |
| Wt. Sample Dry+Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil | | | |
| Moisture Content % | | | |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

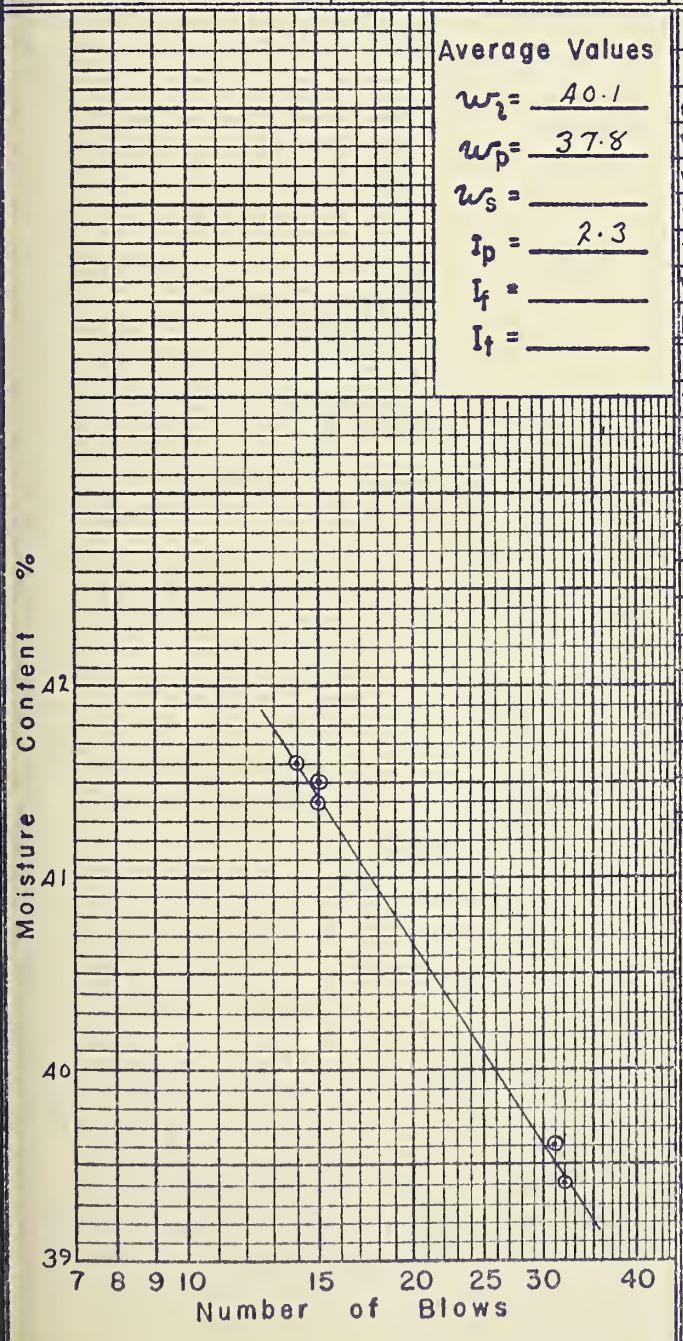
Remarks: _____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest |
| SITE | Crawford Pit |
| SAMPLE | # 9 |
| LOCATION | |
| ~~HOLE~~ | Cycle # 3 DEPTH Day 4 |
| TECHNICIAN | TSM DATE 27-6-59 |

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 31 | 31 | 32 | 14 | 15 | 15 |
| Container No. | V48 | V67 | V88 | V68 | V78 | V57 |
| Wt. Sample Wet + Tare | 91.68 | 86.95 | 99.68 | 108.14 | 103.62 | 93.30 |
| Wt. Sample Dry + Tare | 85.33 | 81.83 | 93.39 | 101.97 | 97.51 | 86.74 |
| Wt. Water | 6.35 | 5.12 | 6.29 | 6.17 | 6.11 | 6.56 |
| Tare Container | 69.29 | 68.91 | 77.43 | 87.13 | 82.78 | 70.91 |
| Wt. of Dry Soil | 16.04 | 12.92 | 15.96 | 14.84 | 14.73 | 15.83 |
| Moisture Content $w$% | 39.6 | 39.6 | 39.4 | 41.6 | 41.5 | 41.4 |




**Average Values**

$w_l$ = 40.1

$w_p$ = 37.8

$w_s$ = _____

$I_p$ = 2.3

$I_f$ = _____

$I_t$ = _____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BR | RD | 28 |
| Wt. Sample Wet+Tare | 59.380 | 62.441 | 43.257 |
| Wt. Sample Dry+Tare | 57.317 | 59.682 | 41.283 |
| Wt. Water | 2.063 | 2.759 | 1.974 |
| Tare Container | 51.756 | 52.326 | 36.030 |
| Wt. of Dry Soil | 5.361 | 7.356 | 5.253 |
| Moisture Content % | 38.5 | 37.5 | 37.5 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

Remarks: _____

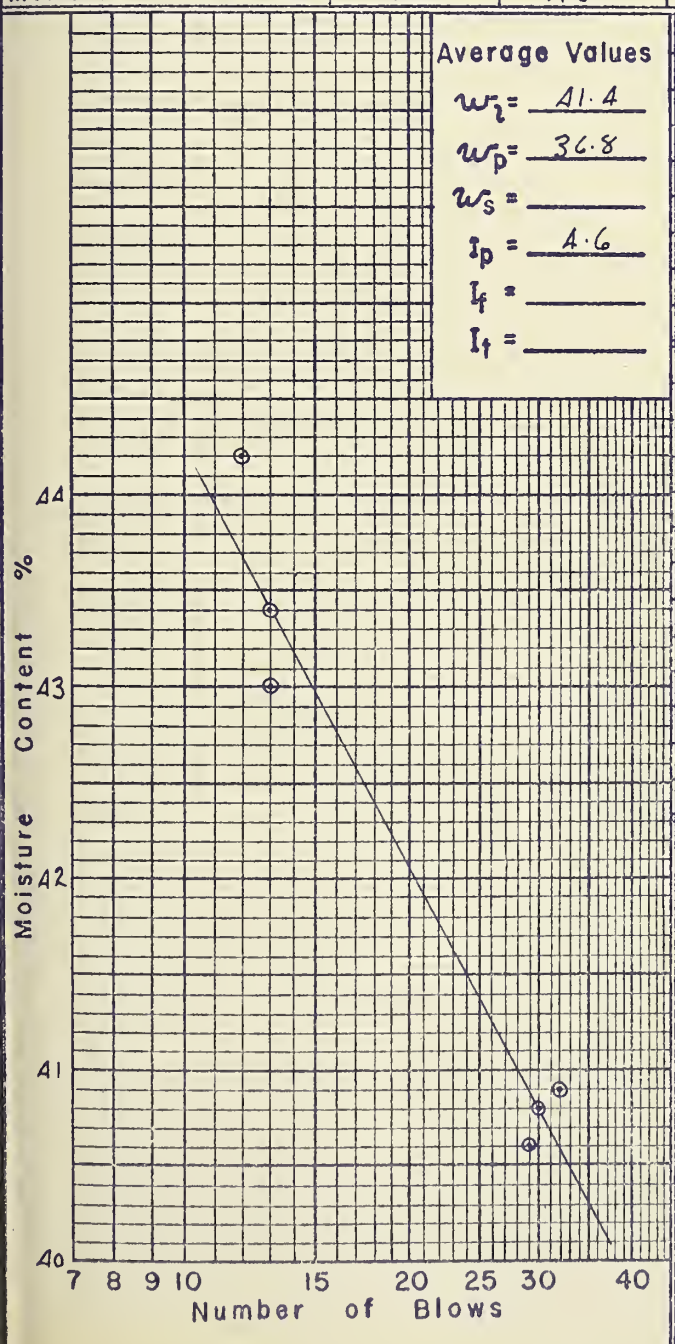
UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 9
LOCATION
HOLE Cycle # 12 DEPTH Day 13
TECHNICIAN T.S.M. DATE 6-7-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 12 | 13 | 13 | 29 | 30 | 32 |
| Container No. | V80 | V51 | V3 | VA1 | V11 | V12 |
| Wt. Sample Wet + Tare | 88.91 | 77.56 | 75.80 | 85.42 | 87.65 | 82.84 |
| Wt. Sample Dry + Tare | 83.73 | 74.10 | 72.28 | 81.68 | 84.53 | 79.23 |
| Wt. Water | 5.18 | 3.46 | 3.52 | 3.74 | 3.12 | 3.61 |
| Tare Container | 72.00 | 66.13 | 64.10 | 72.46 | 76.89 | 70.42 |
| Wt. of Dry Soil | 11.73 | 7.97 | 8.18 | 9.22 | 7.64 | 8.81 |
| Moisture Content $w$% | 44.2 | 43.4 | 43.0 | 40.6 | 40.8 | 40.9 |




Average Values
$w_l$ = 41.4
$w_p$ = 36.8
$w_s$ = ____
$I_p$ = 4.6
$I_f$ = ____
$I_f$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | 1 | AC | AE |
| Wt. Sample Wet+Tare | 42.261 | 57.749 | 62.816 |
| Wt. Sample Dry+Tare | 40.514 | 56.727 | 60.719 |
| Wt. Water | 1.747 | 1.022 | 2.597 |
| Tare Container | 35.680 | 53.639 | 53.087 |
| Wt. of Dry Soil | 4.834 | 3.088 | 7.132 |
| Moisture Content % | 36.2 | 34.0 | 36.4 |

## Plastic ~~Shrinkage~~ Limit

| Trial No. | 4 | 5 | |
|---|---|---|---|
| Container No. | 27 | BK | |
| Wt. Sample Wet + Tare | 47.920 | 59.746 | |
| Wt. Sample Dry + Tare | 45.151 | 57.989 | |
| Wt. Water | 2.769 | 1.757 | |
| Tare Container | 37.724 | 53.262 | |
| Wt. of Dry Soil $W_o$ | 7.427 | 4.727 | |
| Moisture Content $w$% | 37.3 | 37.2 | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

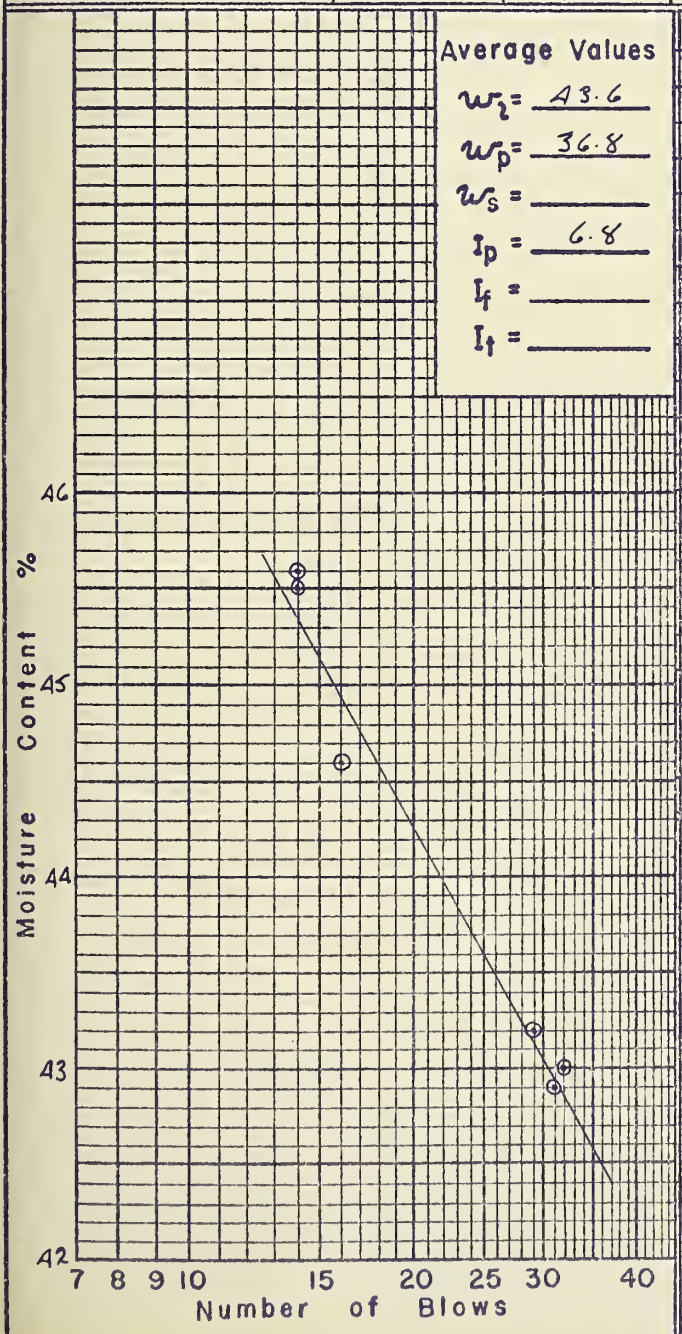
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest. |
| SITE | Crawford Pit |
| SAMPLE | # 9 |
| LOCATION | |
| HOLE | Cycle # 25 DEPTH |
| TECHNICIAN | D.S DATE 22-9-59 |

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 14 | 14 | 16 | 29 | 32 | 31 |
| Container No. | V83 | V59 | V88 | V68 | V58 | V74 |
| Wt. Sample Wet + Tare | 90.89 | 84.65 | 97.71 | 108.50 | 89.50 | 92.24 |
| Wt. Sample Dry + Tare | 84.71 | 79.57 | 91.39 | 102.05 | 83.53 | 85.90 |
| Wt. Water | 6.18 | 5.08 | 5.32 | 6.45 | 5.97 | 6.34 |
| Tare Container | 71.16 | 68.38 | 77.43 | 87.13 | 69.63 | 71.11 |
| Wt. of Dry Soil | 13.55 | 11.19 | 13.96 | 14.92 | 13.90 | 14.79 |
| Moisture Content $w$% | 45.6 | 45.5 | 44.6 | 43.2 | 43.0 | 42.9 |




**Average Values**

$w_l$ = 43.6

$w_p$ = 36.8

$w_s$ = _____

$I_p$ = 6.8

$I_f$ = _____

$I_t$ = _____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AT | 30 | 23 |
| Wt. Sample Wet+Tare | 64.037 | 44.017 | 45.425 |
| Wt. Sample Dry+Tare | 61.288 | 42.015 | 42.918 |
| Wt. Water | 2.749 | 2.002 | 2.507 |
| Tare Container | 53.715 | 36.513 | 36.294 |
| Wt. of Dry Soil | 7.573 | 5.502 | 6.624 |
| Moisture Content % | 36.3 | 36.4 | 37.8 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

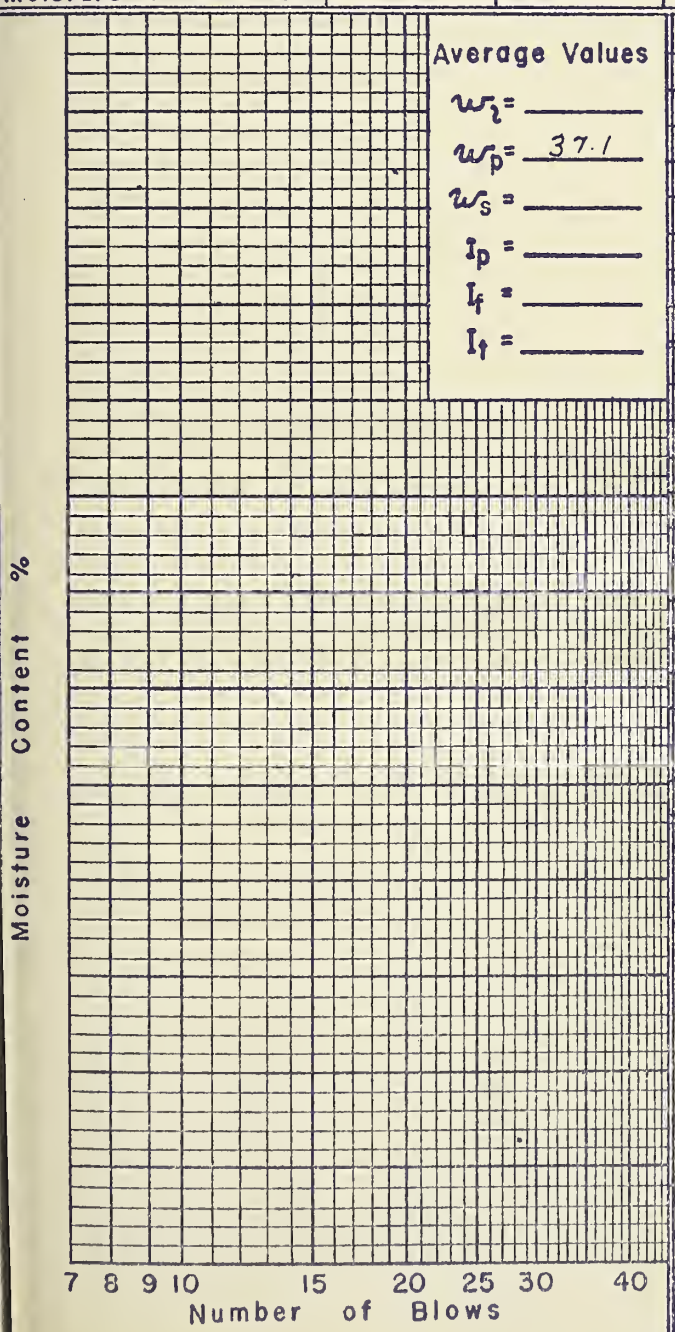
Remarks: _____

# UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 9
LOCATION
NOTE Cycle # 25 DEPTH
TECHNICIAN T.s.-l DATE 22-7-59

### Liquid Limit

| | | | | | | |
|---|---|---|---|---|---|---|
| Trial No. | | | | | | |
| No. of Blows | | | | | | |
| Container No. | | | | | | |
| Wt. Sample Wet + Tare | | | | | | |
| Wt. Sample Dry + Tare | | | | | | |
| Wt. Water | | | | | | |
| Tare Container | | | | | | |
| Wt. of Dry Soil | | | | | | |
| Moisture Content $w$% | | | | | | |




Average Values
$w_l$ = _____
$w_p$ = 37.1
$w_s$ = _____
$I_p$ = _____
$I_f$ = _____
$I_t$ = _____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AV | Am | BA |
| Wt. Sample Wet+Tare | 60.538 | 59.600 | 58.205 |
| Wt. Sample Dry+Tare | 58.874 | 57.857 | 56.471 |
| Wt. Water | 1.664 | 1.743 | 1.734 |
| Tare Container | 54.431 | 53.162 | 51.756 |
| Wt. of Dry Soil | 4.443 | 4.695 | 4.715 |
| Moisture Content % | 37.4 | 37.2 | 36.8 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

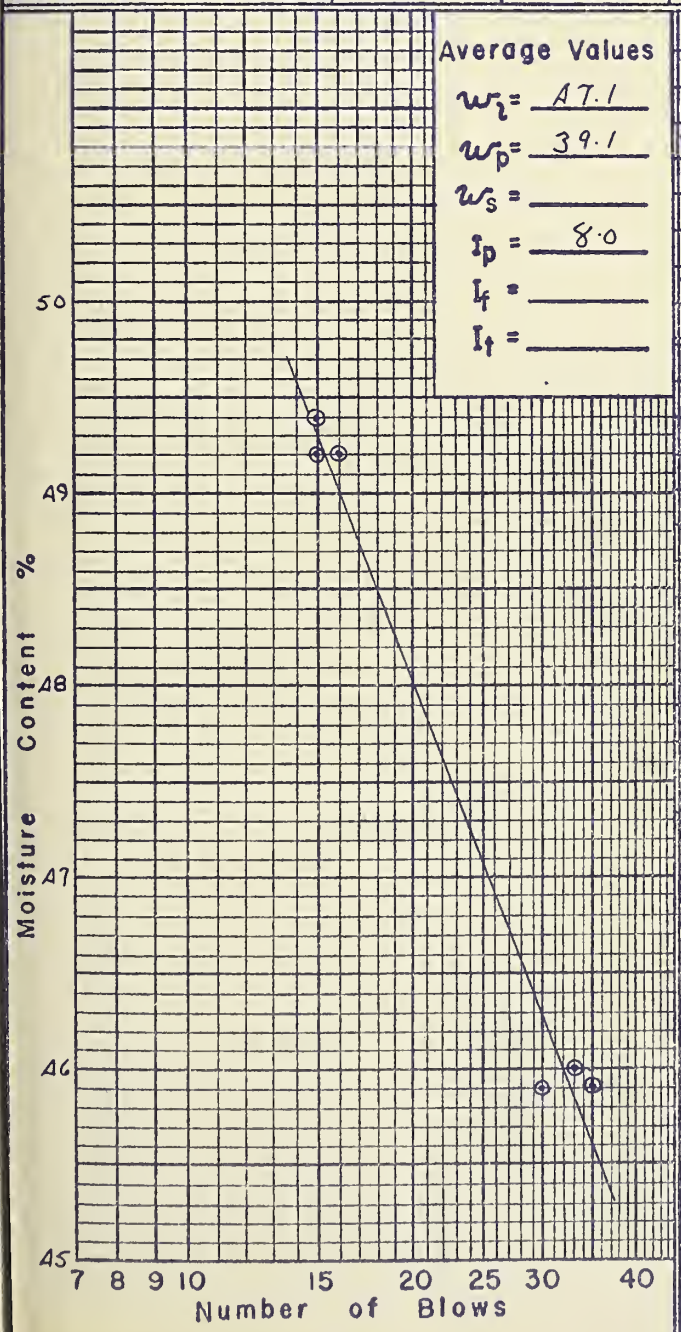
Remarks: Routine check between operators on plastic limit test procedure
D.S. 36.8
T.s.-l. 37.1

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 9
LOCATION
~~HOLE~~ Cycle #48 DEPTH
TECHNICIAN DS DATE 16-8-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 16 | 15 | 15 | 30 | 33 | 35 |
| Container No. | V70 | V30 | V86 | VA5 | VA7 | V67 |
| Wt. Sample Wet + Tare | 100.18 | 89.91 | 94.80 | 91.01 | 85.13 | 87.98 |
| Wt. Sample Dry + Tare | 94.24 | 83.05 | 88.41 | 84.30 | 78.48 | 81.99 |
| Wt. Water | 5.94 | 6.86 | 6.39 | 6.71 | 6.65 | 5.99 |
| Tare Container | 82.18 | 69.10 | 75.50 | 69.69 | 64.00 | 68.91 |
| Wt. of Dry Soil | 12.06 | 13.95 | 12.91 | 14.61 | 14.48 | 13.08 |
| Moisture Content w% | 49.2 | 49.2 | 49.4 | 45.9 | 46.0 | 45.9 |




Average Values
$w_l$ = 47.1
$w_p$ = 39.1
$w_s$ = ____
$I_p$ = 8.0
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BL | AT | AD |
| Wt. Sample Wet+Tare | 65.180 | 65.429 | 62.713 |
| Wt. Sample Dry+Tare | 62.211 | 62.138 | 59.818 |
| Wt. Water | 2.969 | 3.291 | 2.895 |
| Tare Container | 54.741 | 53.715 | 52.326 |
| Wt. of Dry Soil | 7.470 | 8.423 | 7.492 |
| Moisture Content % | 39.7 | 39.1 | 38.6 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content w% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

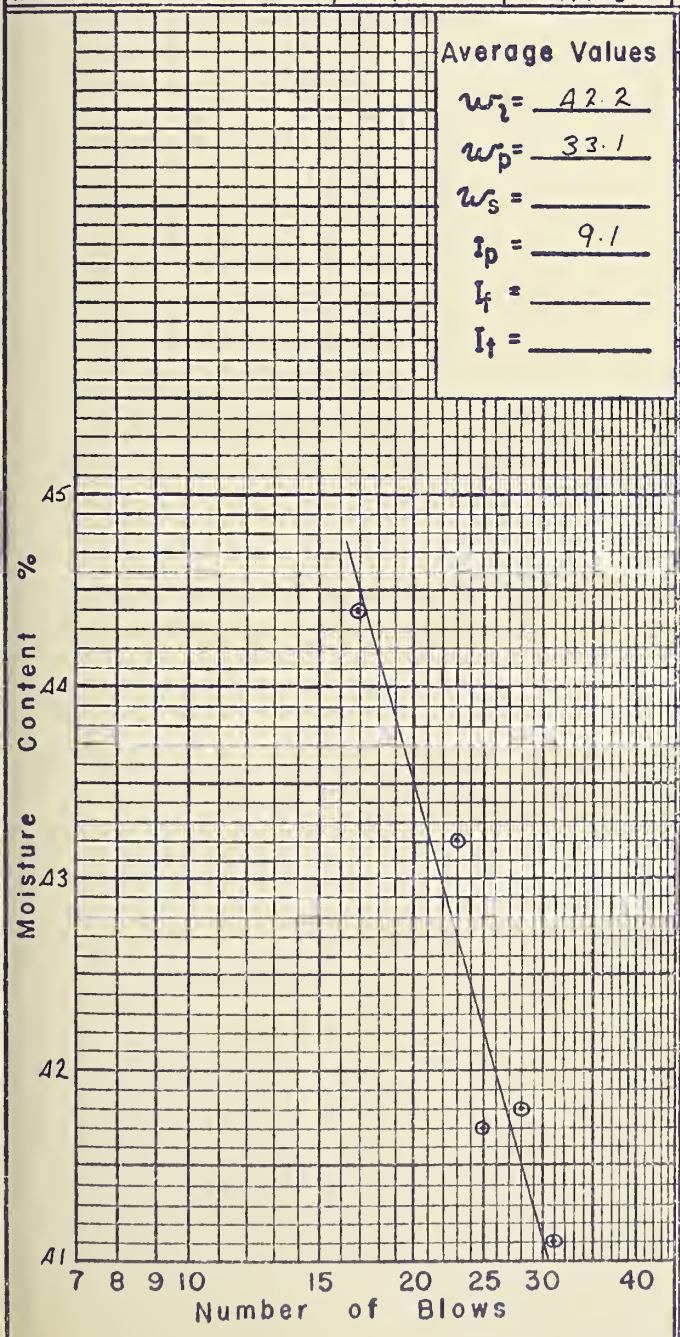
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest. |
| SITE | Crawford Pit |
| SAMPLE | # 10 |
| LOCATION | |
| HOLE | Cycle # 1 DEPTH |
| TECHNICIAN | TSV DATE 26-6-59 |

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 31 | 28 | 25 | 23 | 19 | 17 |
| Container No. | V67 | V88 | V72 | V83 | V63 | V77 |
| Wt. Sample Wet + Tare | 98.88 | 104.34 | 103.24 | 96.42 | 94.39 | 113.16 |
| Wt. Sample Dry + Tare | 90.15 | 96.40 | 93.45 | 88.79 | 86.55 | 101.38 |
| Wt. Water | 8.73 | 7.94 | 9.79 | 7.63 | 7.84 | 11.78 |
| Tare Container | 68.91 | 77.43 | 70.00 | 71.16 | 67.80 | 74.80 |
| Wt. of Dry Soil | 21.24 | 18.97 | 23.45 | 17.63 | 18.75 | 26.58 |
| Moisture Content $w\%$ | 41.1 | 41.8 | 41.7 | 43.2 | 41.8 | 44.4 |




**Average Values**

$w_l$ = 42.2

$w_p$ = 33.1

$w_s$ = _____

$I_p$ = 9.1

$I_f$ = _____

$I_t$ = _____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BI | BE | BW |
| Wt. Sample Wet+Tare | 62.820 | 62.457 | 62.131 |
| Wt. Sample Dry+Tare | 60.883 | 60.447 | 60.280 |
| Wt. Water | 1.937 | 2.010 | 1.851 |
| Tare Container | 54.942 | 54.381 | 54.734 |
| Wt. of Dry Soil | 5.941 | 6.066 | 5.546 |
| Moisture Content % | 32.6 | 33.2 | 33.4 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w\%$ | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

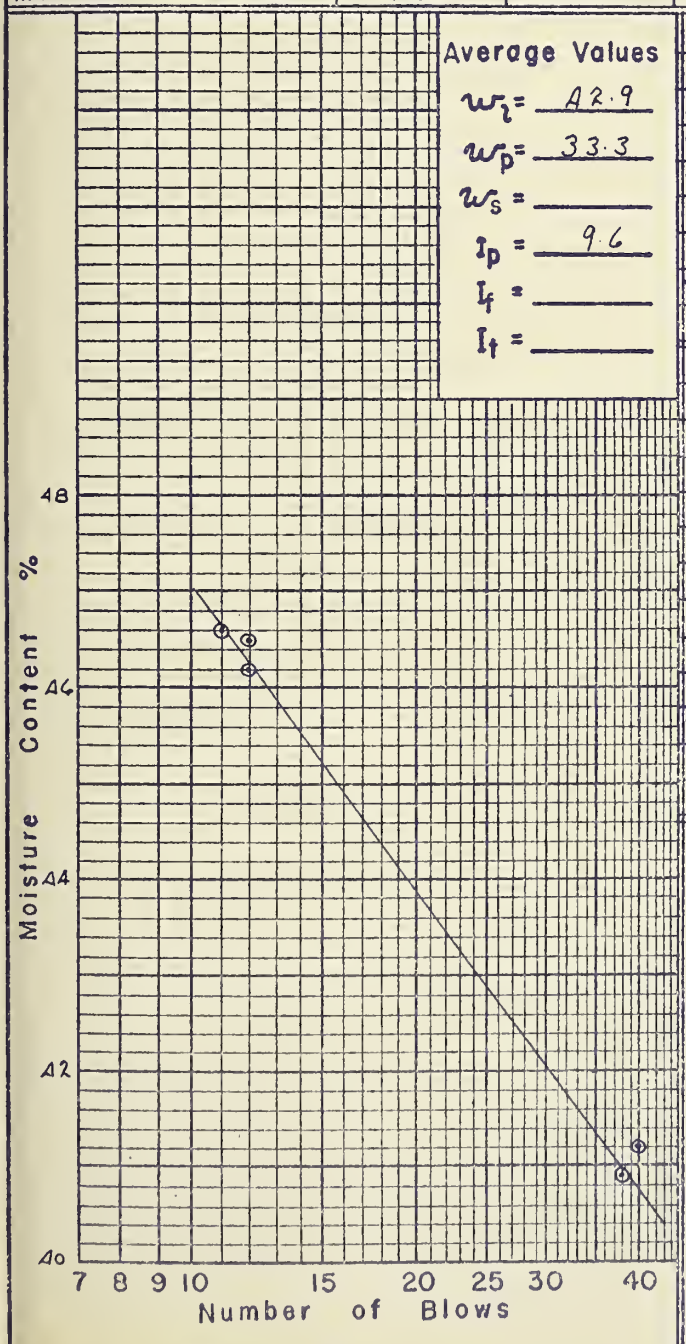
Remarks: _____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 10
LOCATION
~~HOLE~~ Cycle # 3 DEPTH
TECHNICIAN TSM DATE 28-6-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 12 | 11 | 12 | 40 | 38 | 38 |
| Container No. | V50 | V85 | V73 | V84 | V81 | V80 |
| Wt. Sample Wet + Tare | 102.72 | 102.55 | 88.88 | 98.19 | 98.33 | 96.38 |
| Wt. Sample Dry + Tare | 96.03 | 95.51 | 81.71 | 91.54 | 91.90 | 89.30 |
| Wt. Water | 6.69 | 7.04 | 7.17 | 6.65 | 6.43 | 7.08 |
| Tare Container | 81.54 | 80.42 | 66.28 | 75.38 | 76.19 | 72.00 |
| Wt. of Dry Soil | 14.49 | 15.09 | 15.43 | 16.16 | 15.71 | 17.30 |
| Moisture Content $w$% | 46.2 | 46.6 | 46.5 | 41.2 | 40.9 | 40.9 |




Average Values
$w_l$ = 42.9
$w_p$ = 33.3
$w_s$ = ____
$I_p$ = 9.6
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AC | Arn. | BK |
| Wt. Sample Wet+Tare | 61.272 | 62.528 | 59.153 |
| Wt. Sample Dry+Tare | 59.320 | 60.187 | 57.718 |
| Wt. Water | 1.952 | 2.341 | 1.435 |
| Tare Container | 53.639 | 53.162 | 53.262 |
| Wt. of Dry Soil | 5.618 | 7.025 | 4.456 |
| Moisture Content % | 34.4 | 33.4 | 32.2 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

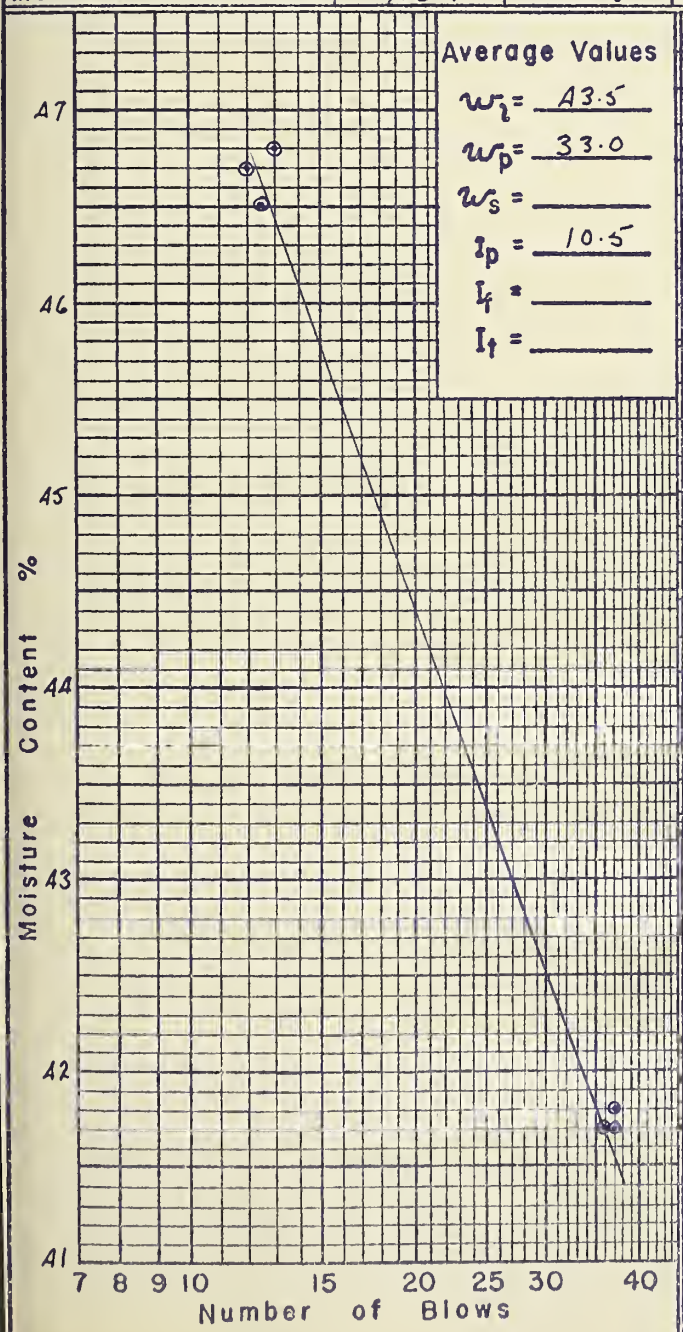
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 10
LOCATION
~~HOLE~~ Cycle # 12 DEPTH
TECHNICIAN TSM DATE 7-7-59

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 12 | 13 | 12½ | 36 | 37 | 37 |
| Container No. | VA2 | VC7 | V73 | VA7 | VA5 | V78 |
| Wt. Sample Wet + Tare | 89.33 | 92.12 | 87.38 | 87.18 | 93.59 | 109.24 |
| Wt. Sample Dry + Tare | 82.35 | 84.72 | 80.68 | 80.36 | 86.56 | 101.43 |
| Wt. Water | 6.98 | 7.40 | 6.70 | 6.82 | 7.03 | 7.81 |
| Tare Container | 67.38 | 68.91 | 66.28 | 64.00 | 69.69 | 82.78 |
| Wt. of Dry Soil | 14.97 | 15.81 | 14.40 | 16.36 | 16.87 | 18.65 |
| Moisture Content w% | 46.7 | 46.8 | 46.5 | 41.7 | 41.7 | 41.8 |




**Average Values**

$w_l$ = 43.5
$w_p$ = 33.0
$w_s$ = ____
$I_p$ = 10.5
$I_f$ = ____
$I_t$ = ____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BL | AS | AM |
| Wt. Sample Wet+Tare | 61.189 | 60.910 | 59.370 |
| Wt. Sample Dry+Tare | 59.621 | 59.235 | 57.814 |
| Wt. Water | 1.568 | 1.675 | 1.556 |
| Tare Container | 50.741 | 54.249 | 53.162 |
| Wt. of Dry Soil | 8.880 | 8.986 | 8.652 |
| Moisture Content % | 32.1 | 33.6 | 33.4 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content w% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

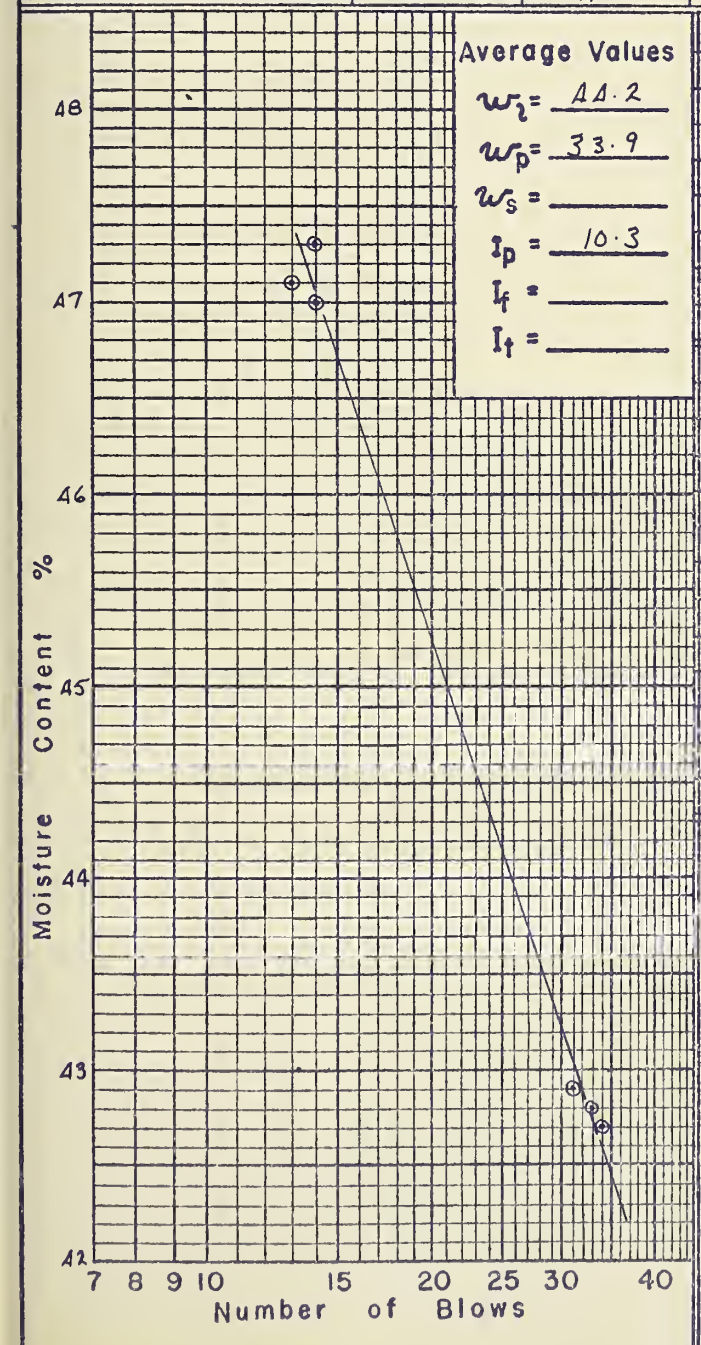
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crowford Pit
SAMPLE # 10
LOCATION
~~HOLE~~ Cycle # 25 DEPTH
TECHNICIAN TSM DATE 23-7-59

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 14 | 14 | 13 | 34 | 31 | 33 |
| Container No. | V88 | V45 | V63 | V58 | V83 | V71 |
| Wt. Sample Wet + Tare | 102.20 | 92.00 | 94.95 | 91.81 | 96.53 | 104.88 |
| Wt. Sample Dry + Tare | 94.25 | 84.87 | 86.25 | 85.17 | 88.91 | 95.82 |
| Wt. Water | 7.95 | 7.13 | 8.70 | 6.64 | 7.62 | 9.06 |
| Tare Container | 77.43 | 69.69 | 67.80 | 69.63 | 71.16 | 74.63 |
| Wt. of Dry Soil | 16.82 | 15.18 | 18.45 | 15.54 | 17.75 | 21.19 |
| Moisture Content $w$% | 47.3 | 47.0 | 47.1 | 42.7 | 42.9 | 42.8 |




Average Values
$w_l$ = 44.2
$w_p$ = 33.9
$w_s$ = ____
$I_p$ = 10.3
$I_f$ = ____
$I_t$ = ____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BL | AD | AE |
| Wt. Sample Wet + Tare | 60.513 | 57.771 | 57.701 |
| Wt. Sample Dry + Tare | 59.040 | 56.396 | 56.550 |
| Wt. Water | 1.473 | 1.375 | 1.151 |
| Tare Container | 54.741 | 52.326 | 53.087 |
| Wt. of Dry Soil | 4.299 | 4.070 | 3.463 |
| Moisture Content % | 34.8 | 33.8 | 33.2 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V - V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V - V_o}{W_o} \times 100\right)$$

Description of Sample: ____

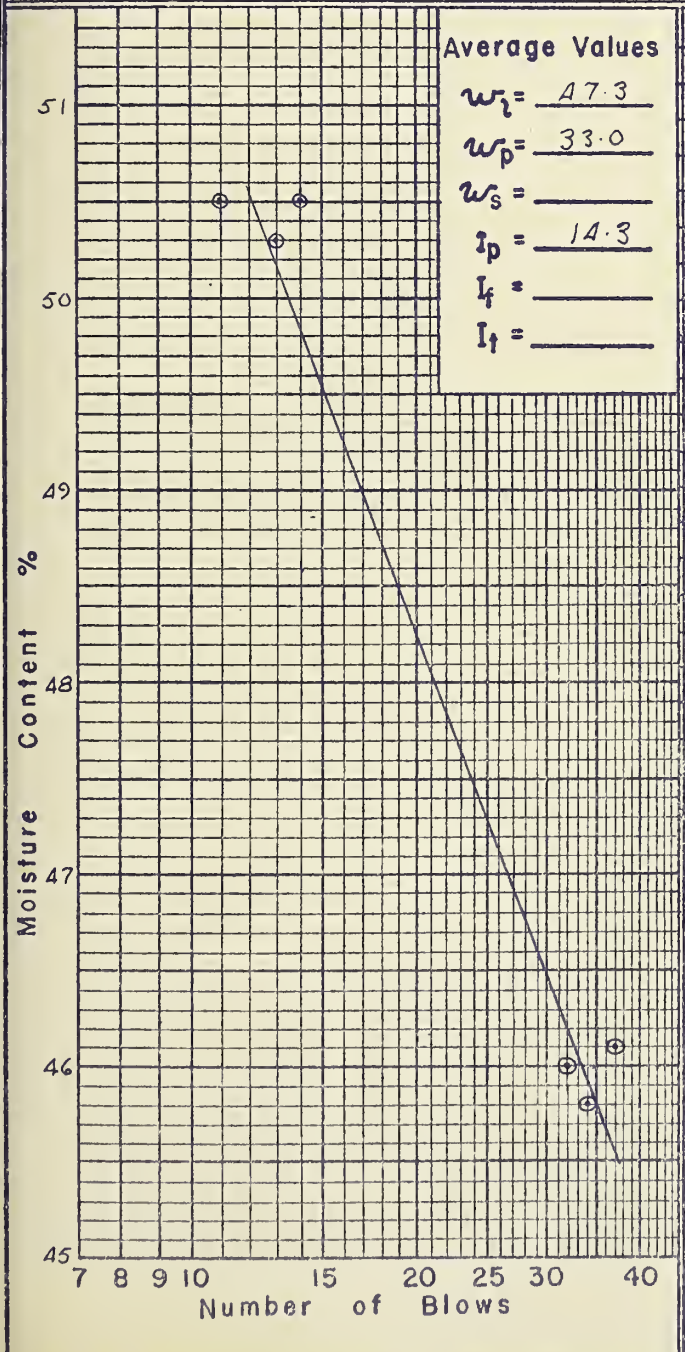
Remarks: ____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest. |
| SITE | Crawford Pit |
| SAMPLE | " 10 |
| LOCATION | |
| HOLE | Cycle " A8 DEPTH |
| TECHNICIAN | DS DATE 16-8-59 |

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 13 | 11 | 14 | 32 | 37 | 34 |
| Container No. | V48 | V80 | V68 | V74 | V50 | V28 |
| Wt. Sample Wet + Tare | 90.21 | 98.03 | 106.11 | 95.00 | 100.04 | 102.90 |
| Wt. Sample Dry + Tare | 83.21 | 89.30 | 99.75 | 87.49 | 94.21 | 96.57 |
| Wt. Water | 7.00 | 8.73 | 6.36 | 7.51 | 5.83 | 6.33 |
| Tare Container | 69.29 | 72.00 | 87.13 | 71.11 | 81.54 | 82.70 |
| Wt. of Dry Soil | 13.92 | 17.30 | 12.62 | 16.38 | 12.67 | 13.87 |
| Moisture Content $w$% | 50.3 | 50.5 | 50.5 | 46.0 | 46.1 | 45.8 |




**Average Values**

$w_l$ = 47.3

$w_p$ = 33.0

$w_s$ = _____

$I_p$ = 14.3

$I_f$ = _____

$I_t$ = _____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BT | AL | AH |
| Wt. Sample Wet+Tare | 57.604 | 59.061 | 58.655 |
| Wt. Sample Dry+Tare | 56.461 | 58.007 | 57.014 |
| Wt. Water | 1.143 | 1.054 | 1.641 |
| Tare Container | 53.062 | 54.741 | 52.057 |
| Wt. of Dry Soil | 3.399 | 3.266 | 4.957 |
| Moisture Content % | 33.7 | 32.3 | 33.1 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

Remarks: _____

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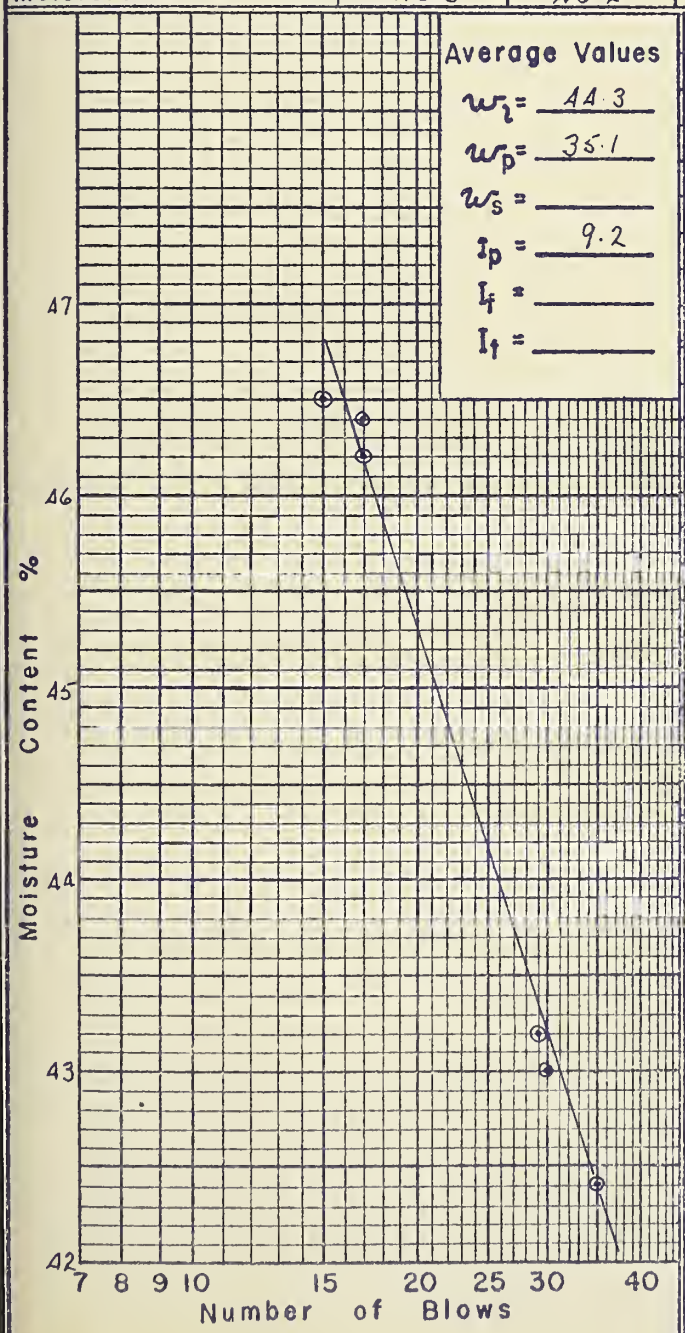
SOIL MECHANICS LABORATORY

# ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest. |
| SITE | Crawford Pit |
| SAMPLE | # 11 |
| LOCATION | |
| HOLE | Cycle #1 DEPTH |
| TECHNICIAN | D.S. DATE 26-6-59 |

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 15 | 17 | 17 | 30 | 29 | 35 |
| Container No. | V74 | V85 | V80 | V73 | V42 | V48 |
| Wt. Sample Wet + Tare | 87.20 | 95.29 | 87.30 | 80.95 | 82.86 | 84.76 |
| Wt. Sample Dry + Tare | 82.09 | 90.60 | 82.45 | 76.54 | 78.19 | 80.15 |
| Wt. Water | 5.11 | 4.69 | 4.85 | 4.41 | 4.67 | 4.61 |
| Tare Container | 71.11 | 80.42 | 72.00 | 66.28 | 67.38 | 69.29 |
| Wt. of Dry Soil | 10.98 | 10.18 | 10.45 | 10.26 | 10.81 | 10.86 |
| Moisture Content $w$% | 46.5 | 46.2 | 46.4 | 43.0 | 43.2 | 42.4 |




**Average Values**

$w_l$ = 44.3
$w_p$ = 35.1
$w_s$ =
$I_p$ = 9.2
$I_f$ =
$I_t$ =

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AV | AH | AT |
| Wt. Sample Wet+Tare | 63.125 | 60.036 | 62.939 |
| Wt. Sample Dry+Tare | 60.901 | 57.953 | 60.360 |
| Wt. Water | 2.224 | 2.083 | 2.579 |
| Tare Container | 54.431 | 52.057 | 53.062 |
| Wt. of Dry Soil | 6.470 | 5.896 | 7.298 |
| Moisture Content % | 34.4 | 35.4 | 35.4 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

Remarks: This sample and #5 set up very hard. Water added and lumps broken up with spatula prior to test.

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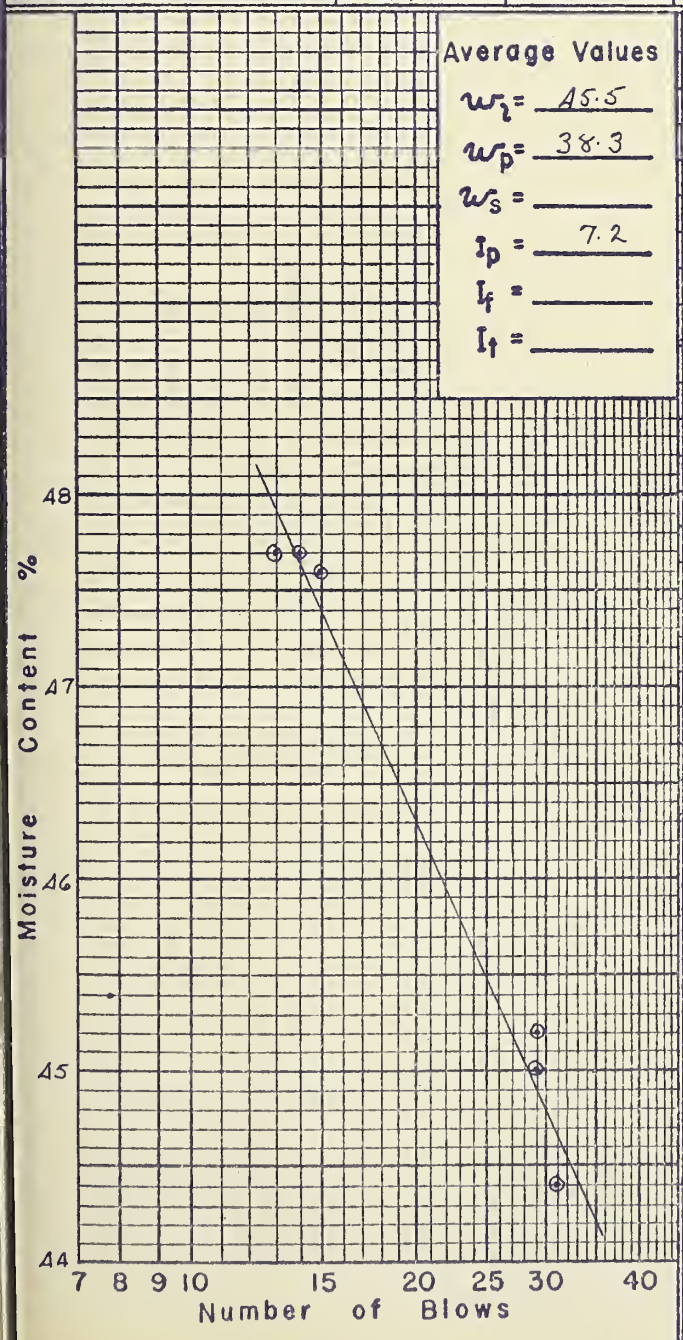
# ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest. |
| SITE | Crawford Pit |
| SAMPLE | # 11 |
| LOCATION | |
| HOLE | Cycle # 3 DEPTH |
| TECHNICIAN | DS DATE 28-6-59 |

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 14 | 13 | 15 | 29 | 29 | 31 |
| Container No. | V78 | V88 | V67 | V68 | V57 | V48 |
| Wt. Sample Wet + Tare | 95.04 | 87.70 | 78.82 | 101.20 | 85.90 | 81.40 |
| Wt. Sample Dry + Tare | 91.08 | 84.38 | 75.62 | 96.82 | 81.25 | 77.68 |
| Wt. Water | 3.96 | 3.32 | 3.20 | 4.38 | 4.65 | 3.72 |
| Tare Container | 82.78 | 77.43 | 68.91 | 87.13 | 70.91 | 69.29 |
| Wt. of Dry Soil | 8.30 | 6.95 | 6.71 | 9.69 | 10.34 | 8.39 |
| Moisture Content $w$% | 47.7 | 47.7 | 47.6 | 45.2 | 45.0 | 44.4 |




**Average Values**

$w_l$ = 45.5

$w_p$ = 38.3

$w_s$ = _____

$I_p$ = 7.2

$I_f$ = _____

$I_t$ = _____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BI | RV | BL |
| Wt. Sample Wet+Tare | 64.643 | 65.842 | 65.860 |
| Wt. Sample Dry+Tare | 61.949 | 62.657 | 62.805 |
| Wt. Water | 2.694 | 3.185 | 3.055 |
| Tare Container | 54.942 | 54.431 | 54.741 |
| Wt. of Dry Soil | 7.007 | 8.226 | 8.054 |
| Moisture Content % | 38.4 | 38.7 | 37.9 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

Remarks: _____

# UNIVERSITY of ALBERTA
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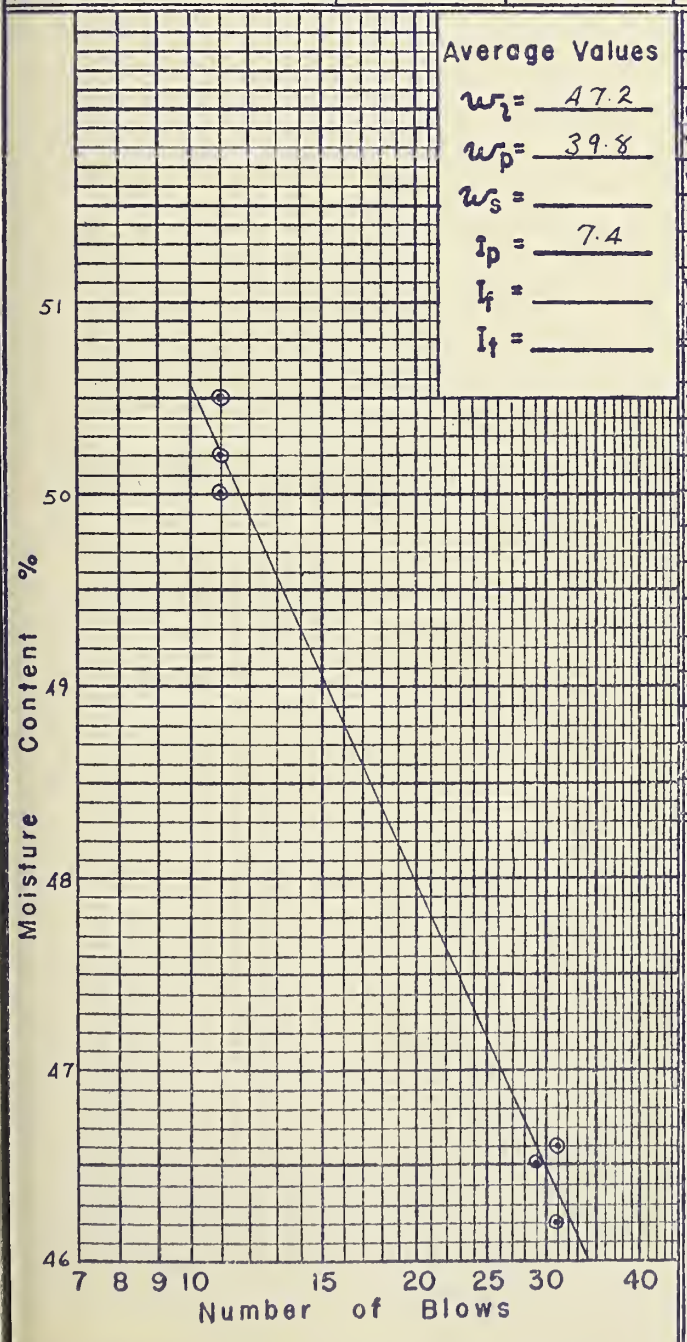
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest. |
| SITE | Crawford Pit |
| SAMPLE | # 11 |
| LOCATION | |
| HOLE | Cycle # 12 DEPTH |
| TECHNICIAN | D.S DATE 7-7-59 |

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 11 | 11 | 11 | 31 | 29 | 32 |
| Container No. | V66 | V6 | V59 | V51 | V3 | V80 |
| Wt. Sample Wet + Tare | 78.35 | 87.50 | 78.92 | 77.22 | 77.40 | 86.07 |
| Wt. Sample Dry + Tare | 74.38 | 83.90 | 75.40 | 73.72 | 73.18 | 81.60 |
| Wt. Water | 3.97 | 3.60 | 3.52 | 3.50 | 4.22 | 4.47 |
| Tare Container | 66.43 | 76.78 | 68.38 | 66.13 | 64.10 | 72.00 |
| Wt. of Dry Soil | 7.95 | 7.12 | 7.02 | 7.59 | 9.08 | 9.60 |
| Moisture Content w% | 50.0 | 50.5 | 50.2 | 46.2 | 46.5 | 46.6 |




**Average Values**

$w_l$ = 47.2

$w_p$ = 39.8

$w_s$ = _____

$I_p$ = 7.4

$I_f$ = _____

$I_t$ = _____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AT | 28 | 32 |
| Wt. Sample Wet+Tare | 61.452 | 46.056 | 43.212 |
| Wt. Sample Dry+Tare | 59.242 | 43.189 | 41.098 |
| Wt. Water | 2.210 | 2.867 | 2.114 |
| Tare Container | 53.715 | 36.030 | 35.747 |
| Wt. of Dry Soil | 5.527 | 7.159 | 5.351 |
| Moisture Content % | 40.0 | 40.0 | 39.4 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content w% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

Remarks: _____

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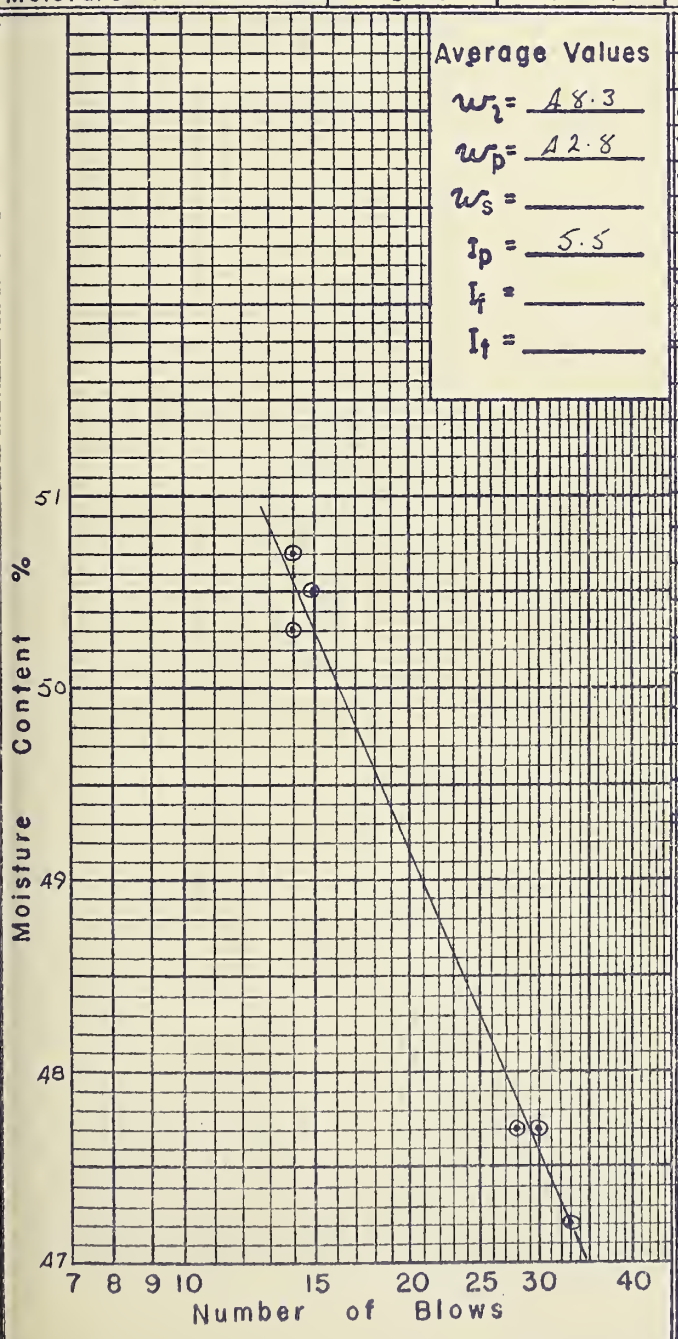
SOIL MECHANICS LABORATORY

# ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest. |
| SITE | Crawford Pit |
| SAMPLE | # 11 |
| LOCATION | |
| HOLE | Cycle # 25 DEPTH |
| TECHNICIAN | DS DATE 23-7-59 |

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 15 | 14 | 14 | 30 | 28 | 33 |
| Container No. | V72 | V61 | V7 | V73 | V81 | V69 |
| Wt. Sample Wet + Tare | 91.08 | 95.54 | 90.26 | 86.74 | 97.44 | 89.96 |
| Wt. Sample Dry + Tare | 84.01 | 89.20 | 83.20 | 80.13 | 90.58 | 83.37 |
| Wt. Water | 7.07 | 6.34 | 7.06 | 6.61 | 6.86 | 6.59 |
| Tare Container | 70.00 | 76.74 | 69.16 | 66.28 | 76.19 | 69.41 |
| Wt. of Dry Soil | 14.01 | 12.50 | 14.04 | 13.85 | 14.39 | 13.96 |
| Moisture Content $w$% | 50.5 | 50.7 | 50.3 | 47.7 | 47.7 | 47.2 |




**Average Values**

$w_l$ = 48.3

$w_p$ = 42.8

$w_s$ = _____

$I_p$ = 5.5

$I_f$ = _____

$I_t$ = _____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BI | A5 | Am |
| Wt. Sample Wet+Tare | 62.162 | 61.766 | 58.311 |
| Wt. Sample Dry+Tare | 59.971 | 59.543 | 56.769 |
| Wt. Water | 2.191 | 2.223 | 1.542 |
| Tare Container | 54.942 | 54.249 | 53.162 |
| Wt. of Dry Soil | 5.029 | 5.294 | 3.607 |
| Moisture Content % | 43.6 | 42.0 | 42.8 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

Remarks: _____

# UNIVERSITY of ALBERTA
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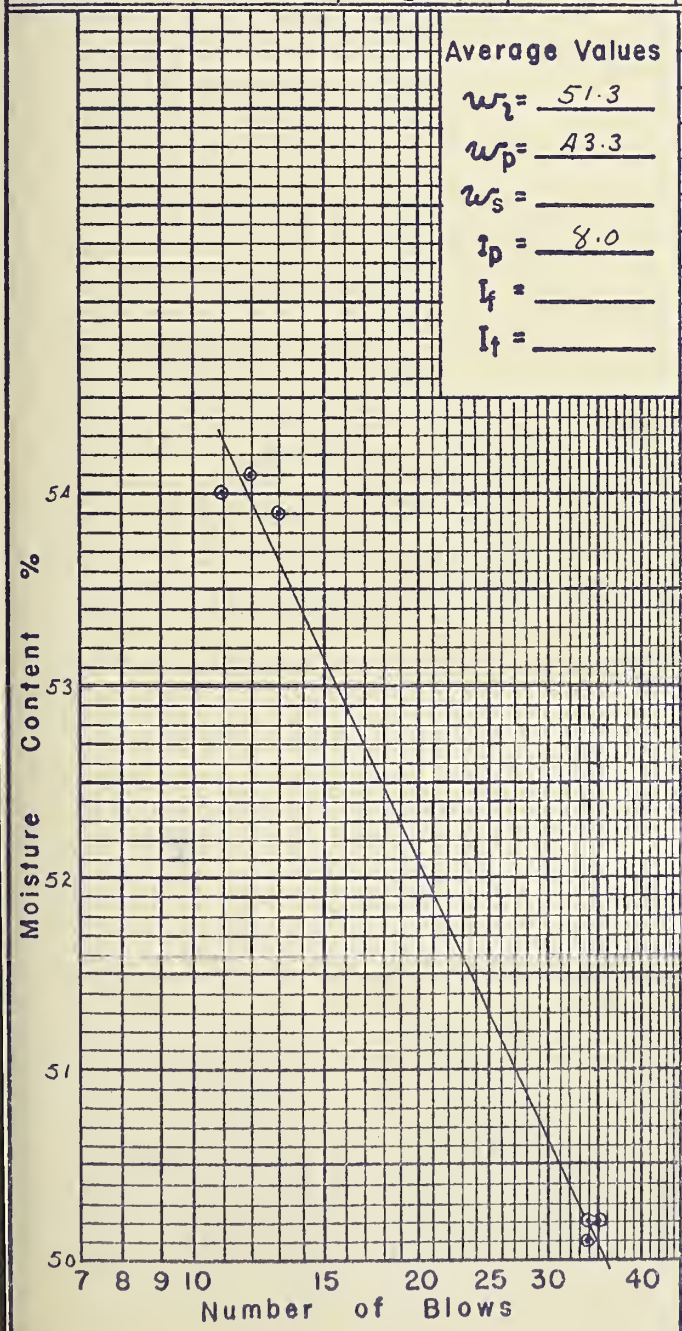
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest. |
| SITE | Crawford Pit |
| SAMPLE | # 11 |
| LOCATION | |
| HOLE | Cycle # 48 DEPTH |
| TECHNICIAN | DS DATE 17-8-59 |

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 13 | 12 | 11 | 34 | 34 | 35 |
| Container No. | V63 | V71 | V58 | V84 | V90 | V61 |
| Wt. Sample Wet + Tare | 90.32 | 93.07 | 87.45 | 94.01 | 91.30 | 94.10 |
| Wt. Sample Dry + Tare | 82.42 | 86.60 | 81.21 | 87.79 | 85.11 | 88.29 |
| Wt. Water | 7.90 | 6.47 | 6.24 | 6.22 | 6.19 | 5.81 |
| Tare Container | 67.80 | 74.63 | 69.63 | 75.38 | 72.80 | 76.70 |
| Wt. of Dry Soil | 14.62 | 11.97 | 11.58 | 12.41 | 12.31 | 11.59 |
| Moisture Content $w$% | 53.9 | 54.1 | 54.0 | 50.1 | 50.2 | 50.2 |




**Average Values**

$w_l$ = 51.3

$w_p$ = 43.3

$w_s$ = _____

$I_p$ = 8.0

$I_f$ = _____

$I_t$ = _____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AP | AV | BA |
| Wt. Sample Wet+Tare | 60.195 | 58.930 | 58.335 |
| Wt. Sample Dry+Tare | 58.175 | 57.580 | 56.381 |
| Wt. Water | 2.020 | 1.350 | 1.954 |
| Tare Container | 53.395 | 54.431 | 51.756 |
| Wt. of Dry Soil | 4.780 | 3.049 | 4.625 |
| Moisture Content % | 42.2 | 44.2 | 42.2 |

## ~~Shrinkage~~ Limit

| Trial No. | 4 | | |
|---|---|---|---|
| Container No. | A0 | | |
| Wt. Sample Wet + Tare | 58.174 | | |
| Wt. Sample Dry + Tare | 56.880 | | |
| Wt. Water | 1.294 | | |
| Tare Container | 53.896 | | |
| Wt. of Dry Soil $W_o$ | 2.984 | | |
| Moisture Content $w$% | 43.4 | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V - V_o}{W_o} \times 100\right)$$

Description of Sample: _____

Remarks: _____

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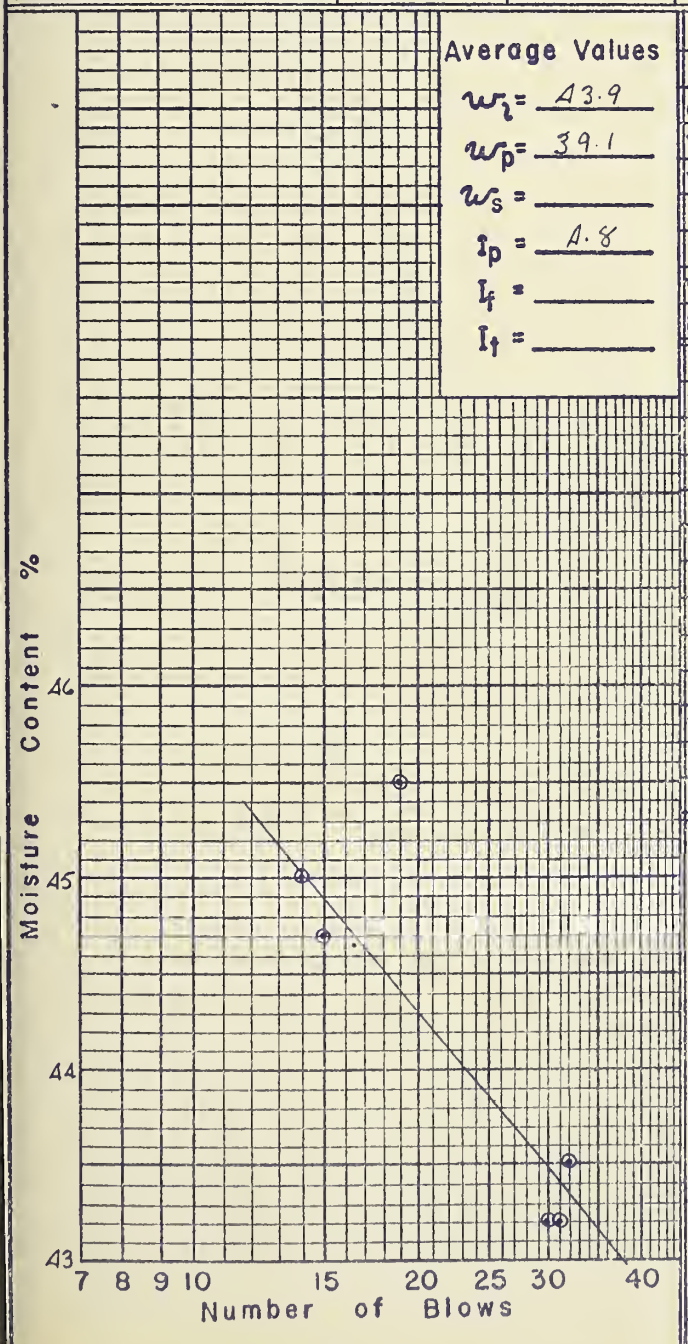
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest. |
| SITE | Crawford Pit |
| SAMPLE | # 12 |
| LOCATION | |
| HOLE | Cycle # 1 DEPTH |
| TECHNICIAN | DS DATE 26-6-59 |

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 32 | 31 | 32 | 14 | 15 | 19 |
| Container No. | V78 | V62 | V69 | V71 | V70 | V68 |
| Wt. Sample Wet + Tare | 97.18 | 81.00 | 84.37 | 87.71 | 96.50 | 101.32 |
| Wt. Sample Dry + Tare | 92.81 | 76.19 | 79.86 | 83.65 | 92.06 | 96.91 |
| Wt. Water | 4.37 | 4.81 | 4.51 | 4.06 | 4.44 | 4.41 |
| Tare Container | 82.78 | 65.05 | 69.41 | 74.63 | 82.12 | 87.13 |
| Wt. of Dry Soil | 10.03 | 11.14 | 10.45 | 9.02 | 9.94 | 9.78 |
| Moisture Content $w$% | 43.5 | 43.2 | 43.2 | 45.0 | 44.7 | 45.5 |




**Average Values**

$w_l$ = 43.9

$w_p$ = 39.1

$w_s$ = _____

$I_p$ = 4.8

$I_f$ = _____

$I_t$ = _____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AE | 28 | 22 |
| Wt. Sample Wet+Tare | 62.946 | 43.095 | 45.737 |
| Wt. Sample Dry+Tare | 60.091 | 41.114 | 43.007 |
| Wt. Water | 2.855 | 1.981 | 2.730 |
| Tare Container | 53.087 | 36.030 | 35.747 |
| Wt. of Dry Soil | 7.004 | 5.084 | 7.260 |
| Moisture Content % | 40.8 | 39.0 | 37.6 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

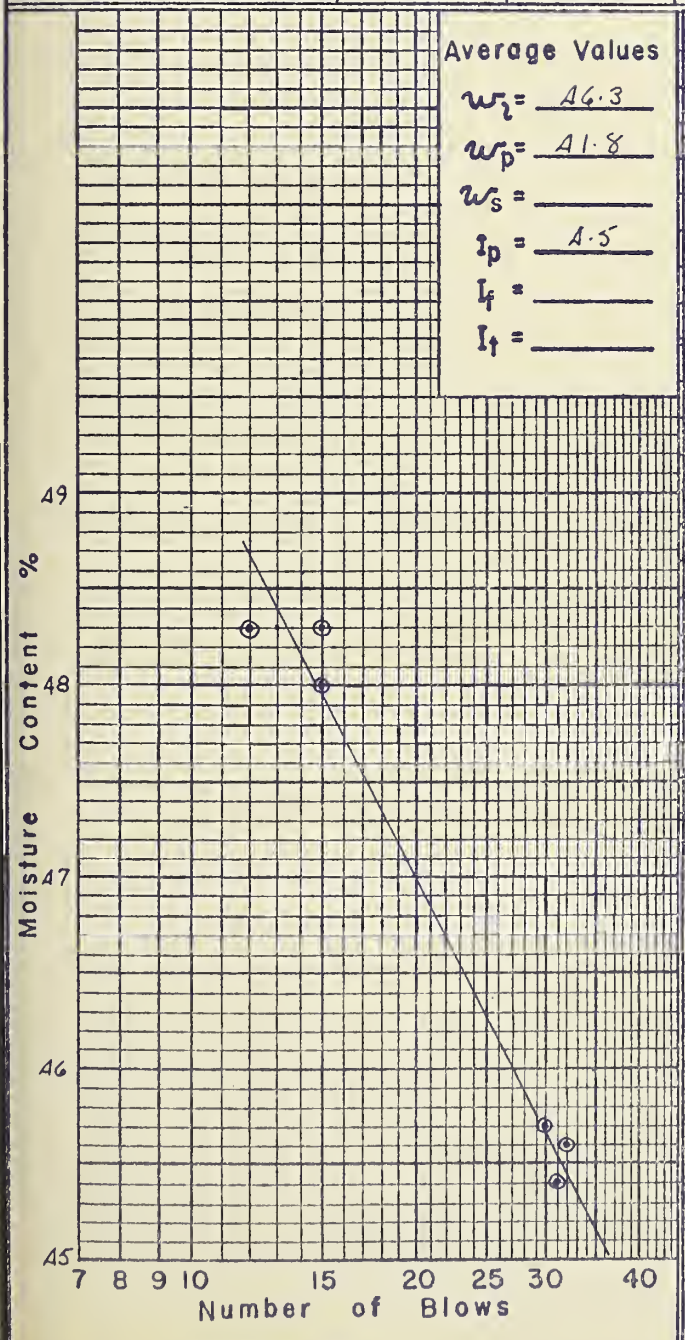
Remarks: _____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest. |
| SITE | Crawford Pit |
| SAMPLE | # 12 |
| LOCATION | |
| HOLE | Cycle # 3 DEPTH |
| TECHNICIAN | DS DATE 28-6-59 |

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 15 | 15 | 12 | 31 | 30 | 32 |
| Container No. | V63 | V51 | V61 | V47 | V46 | V29 |
| Wt. Sample Wet + Tare | 81.77 | 80.05 | 89.55 | 78.51 | 98.76 | 84.60 |
| Wt. Sample Dry + Tare | 77.22 | 75.53 | 85.36 | 73.98 | 94.04 | 78.90 |
| Wt. Water | 4.55 | 4.52 | 4.19 | 4.53 | 4.72 | 5.70 |
| Tare Container | 67.80 | 66.13 | 76.70 | 64.00 | 83.71 | 66.40 |
| Wt. of Dry Soil | 9.42 | 9.40 | 8.66 | 9.98 | 10.33 | 12.50 |
| Moisture Content $w$% | 48.3 | 48.0 | 48.3 | 45.4 | 45.7 | 45.6 |




**Average Values**

$w_l$ = 46.3

$w_p$ = 41.8

$w_s$ = _____

$I_p$ = 4.5

$I_f$ = _____

$I_t$ = _____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | AE | AS | AT |
| Wt. Sample Wet+Tare | 65.076 | 65.688 | 66630 |
| Wt. Sample Dry+Tare | 61.536 | 62.312 | 62.825 |
| Wt. Water | 3.540 | 3.376 | 3.805 |
| Tare Container | 53.087 | 54.249 | 53.715 |
| Wt. of Dry Soil | 8.449 | 8.063 | 9.110 |
| Moisture Content % | 41.9 | 41.8 | 41.7 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

_____

_____

_____

_____

Remarks: _____

_____

_____

_____

_____

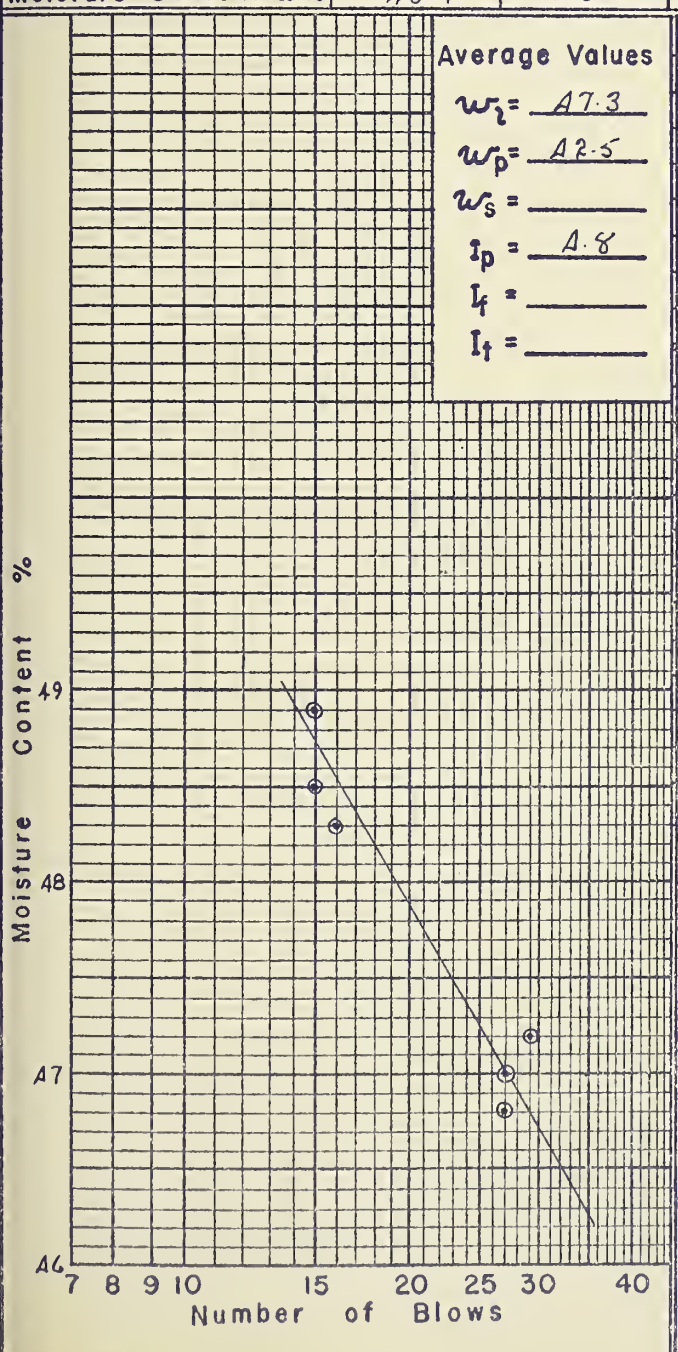
_____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 12
LOCATION
~~NOTE~~ Cycle # 12 DEPTH
TECHNICIAN DS DATE 7-7-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 15 | 15 | 16 | 29 | 27 | 28 |
| Container No. | V72 | V61 | V83 | V9 | V48 | V46 |
| Wt. Sample Wet + Tare | 80.90 | 86.74 | 83.04 | 91.81 | 81.47 | 97.10 |
| Wt. Sample Dry + Tare | 77.32 | 83.46 | 79.17 | 87.89 | 77.59 | 92.82 |
| Wt. Water | 3.58 | 3.28 | 3.87 | 3.92 | 3.88 | 4.28 |
| Tare Container | 70.00 | 76.70 | 71.16 | 79.58 | 69.29 | 83.71 |
| Wt. of Dry Soil | 7.32 | 6.76 | 8.01 | 8.31 | 8.30 | 9.11 |
| Moisture Content $w$% | 48.9 | 48.5 | 48.3 | 47.2 | 46.8 | 47.0 |




**Average Values**

$w_l$ = 47.3
$w_p$ = 42.5
$w_s$ = ____
$I_p$ = 4.8
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | 3 | 27 | BE |
| Wt. Sample Wet+Tare | 39.475 | 44.969 | 63.149 |
| Wt. Sample Dry+Tare | 38.187 | 42.803 | 60.531 |
| Wt. Water | 1.288 | 2.166 | 2.618 |
| Tare Container | 35.190 | 37.724 | 54.381 |
| Wt. of Dry Soil | 2.997 | 5.079 | 6.150 |
| Moisture Content % | 43.0 | 42.6 | 42.5 |

## ~~Shrinkage~~ Limit

| Trial No. | 4 | 5 | |
|---|---|---|---|
| Container No. | 30 | 23 | |
| Wt. Sample Wet + Tare | 43.681 | 42.770 | |
| Wt. Sample Dry + Tare | 41.562 | 40.860 | |
| Wt. Water | 2.119 | 1.910 | |
| Tare Container | 36.513 | 36.294 | |
| Wt. of Dry Soil $W_o$ | 5.049 | 4.566 | |
| Moisture Content $w$% | 41.8 | 41.8 | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

Remarks: ____

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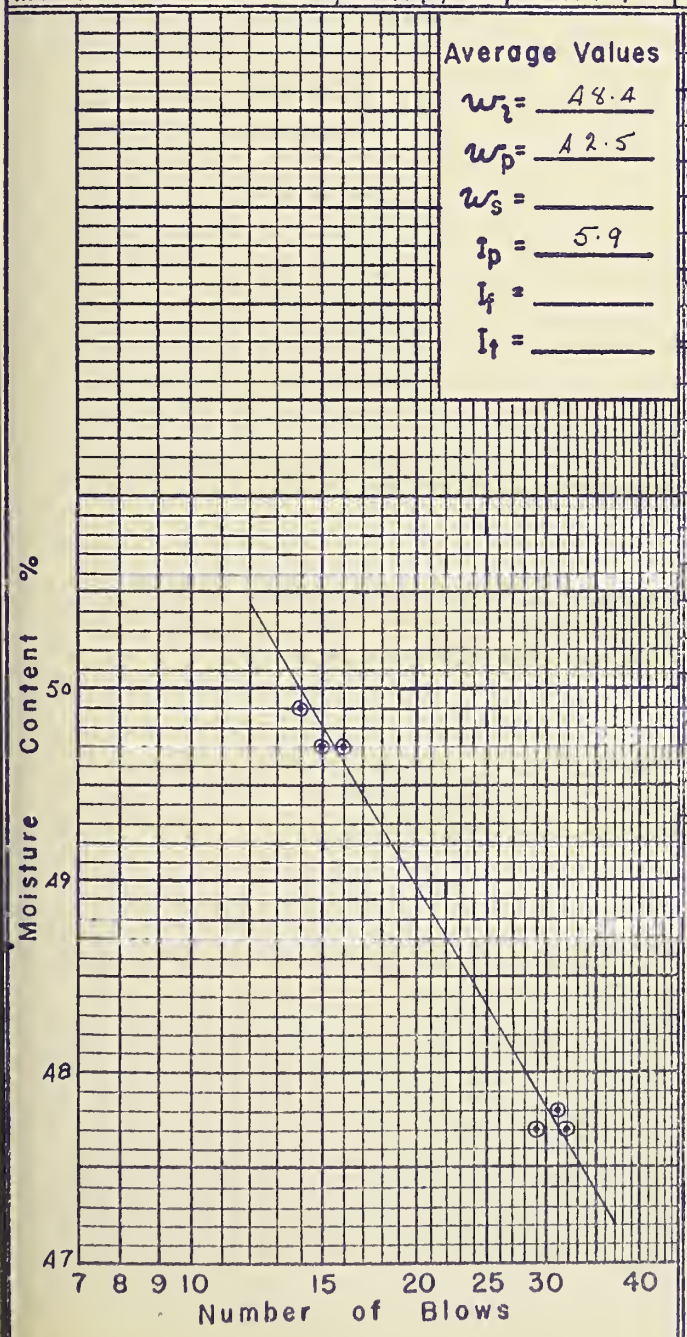
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

| | |
|---|---|
| PROJECT | Freeze Thaw Invest. |
| SITE | Crawford Pit |
| SAMPLE | # 12 |
| LOCATION | |
| ~~HOLE~~ | Cycle # 25 DEPTH |
| TECHNICIAN | DS DATE 23-7-59 |

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 16 | 14 | 15 | 31 | 29 | 32 |
| Container No. | V A2 | V 70 | V 84 | V 6 | V 90 | V 9 |
| Wt. Sample Wet + Tare | 87.71 | 102.10 | 93.62 | 98.70 | 95.10 | 103.21 |
| Wt. Sample Dry + Tare | 80.96 | 95.47 | 87.56 | 91.60 | 87.90 | 95.58 |
| Wt. Water | 6.75 | 6.63 | 6.06 | 7.10 | 7.20 | 7.63 |
| Tare Container | 67.38 | 82.78 | 75.38 | 76.78 | 72.80 | 79.58 |
| Wt. of Dry Soil | 13.58 | 13.29 | 12.18 | 14.82 | 15.10 | 16.00 |
| Moisture Content w% | 49.7 | 49.9 | 49.7 | 47.8 | 47.7 | 47.7 |




**Average Values**

$w_l$ = 48.4

$w_p$ = 42.5

$w_s$ = _____

$I_p$ = 5.9

$I_f$ = _____

$I_t$ = _____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | 22 | 27 | 28 |
| Wt. Sample Wet+Tare | 43.431 | 44.350 | 43.860 |
| Wt. Sample Dry+Tare | 41.126 | 42.392 | 41.506 |
| Wt. Water | 2.305 | 1.958 | 2.354 |
| Tare Container | 35.747 | 37.724 | 36.030 |
| Wt. of Dry Soil | 5.379 | 4.668 | 5.476 |
| Moisture Content % | 42.7 | 42.0 | 42.9 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content w% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: _____

Remarks: _____

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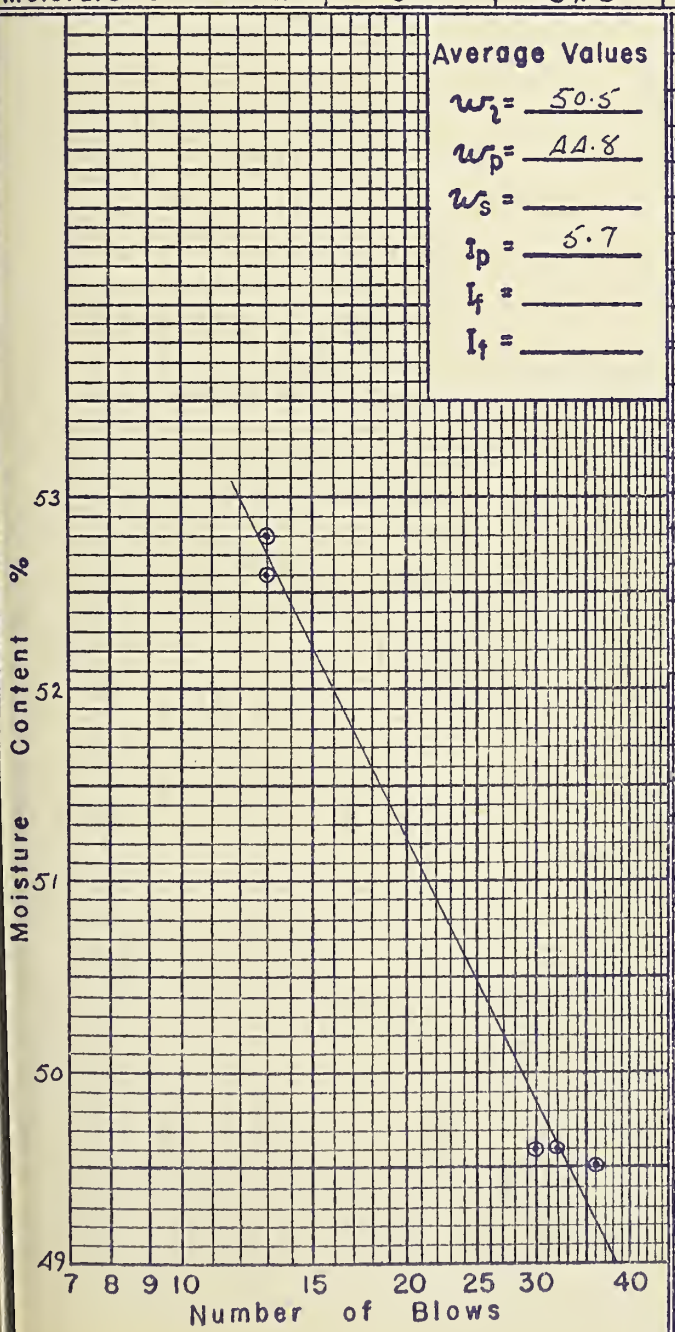
SOIL MECHANICS LABORATORY
# ATTERBERG LIMITS

PROJECT Freeze Thaw Invest.
SITE Crawford Pit
SAMPLE # 12
LOCATION
~~HOLE~~ Cycle #48 DEPTH
TECHNICIAN DS DATE 17-8-59

## Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 13 | 13 | 13 | 30 | 32 | 36 |
| Container No. | V89 | V80 | V81 | V90 | V63 | V84 |
| Wt. Sample Wet + Tare | 95.76 | 91.50 | 96.92 | 93.83 | 87.85 | 101.13 |
| Wt. Sample Dry + Tare | 88.52 | 84.77 | 89.76 | 88.86 | 81.20 | 92.61 |
| Wt. Water | 7.24 | 6.73 | 7.16 | 6.97 | 6.65 | 8.52 |
| Tare Container | 74.77 | 72.00 | 76.19 | 72.80 | 67.80 | 75.38 |
| Wt. of Dry Soil | 13.75 | 12.77 | 13.57 | 14.06 | 13.40 | 17.23 |
| Moisture Content $w$% | 52.6 | 52.6 | 52.8 | 49.6 | 49.6 | 49.5 |




Average Values
$w_l$ = 50.5
$w_p$ = 49.8
$w_s$ = ____
$I_p$ = 5.7
$I_f$ = ____
$I_t$ = ____

## Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | 23 | 30 | BW |
| Wt. Sample Wet+Tare | 40.598 | 41.083 | 59.824 |
| Wt. Sample Dry+Tare | 39.267 | 39.682 | 58.241 |
| Wt. Water | 1.331 | 1.401 | 1.583 |
| Tare Container | 36.294 | 36.513 | 54.734 |
| Wt. of Dry Soil | 2.973 | 3.169 | 3.507 |
| Moisture Content % | 44.9 | 44.2 | 45.2 |

## Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

Remarks: ____

# APPENDIX C

## Analysis of Sieved Fractions of Crawford Pit Material Used in the Permeability Tests

UNIVERSITY of ALBERTA
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SOIL MECHANICS LABORATORY

# MOISTURE CONTENT

PROJECT Permeability Investigation
SITE Crawford Pit
SAMPLE Sieved Stock Fractions
LOCATION
HOLE DEPTH
TECHNICIAN TSM DATE

| ~~Hole No.~~ Fraction | -#4+#10 | -#10+#40 | -#40 | | | |
|---|---|---|---|---|---|---|
| Depth | | | | | | |
| Sample No. | 1 | 2 | 3 | | | |
| Container No. | V69 | V68 | V67 | | | |
| Wt. Sample Wet + Tare | 115.75 | 137.74 | 130.21 | | | |
| Wt. Sample Dry + Tare | 115.41 | 136.68 | 127.92 | | | |
| Wt. Water | 0.34 | 1.06 | 2.29 | | | |
| Tare Container | 69.40 | 87.12 | 68.90 | | | |
| Wt. of Dry Soil | 46.01 | 49.56 | 59.02 | | | |
| Moisture Content $w$ % | 0.74 | 2.16 | 3.88 | | | |

| Hole No | | | | | | |
|---|---|---|---|---|---|---|
| Depth | | | | | | |
| Sample No. | | | | | | |
| Container No. | | | | | | |
| Wt. Sample Wet + Tare | | | | | | |
| Wt. Sample Dry + Tare | | | | | | |
| Wt. Water | | | | | | |
| Tare Container | | | | | | |
| Wt. of Dry Soil | | | | | | |
| Moisture Content $w$ % | | | | | | |

| Hole No. | | | | | | |
|---|---|---|---|---|---|---|
| Depth | | | | | | |
| Sample No. | | | | | | |
| Container No. | | | | | | |
| Wt. Sample Wet + Tare | | | | | | |
| Wt. Sample Dry + Tare | | | | | | |
| Wt. Water | | | | | | |
| Tare Container | | | | | | |
| Wt. of Dry Soil | | | | | | |
| Moisture Content $w$% | | | | | | |

Remarks: _____

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# SIEVE ANALYSIS

PROJECT Permeability Investigation
SITE Crowford Pit
SAMPLE Stock - #4 + #10 Fraction
LOCATION
HOLE DEPTH
TECHNICIAN TS-1 DATE 6-8-59

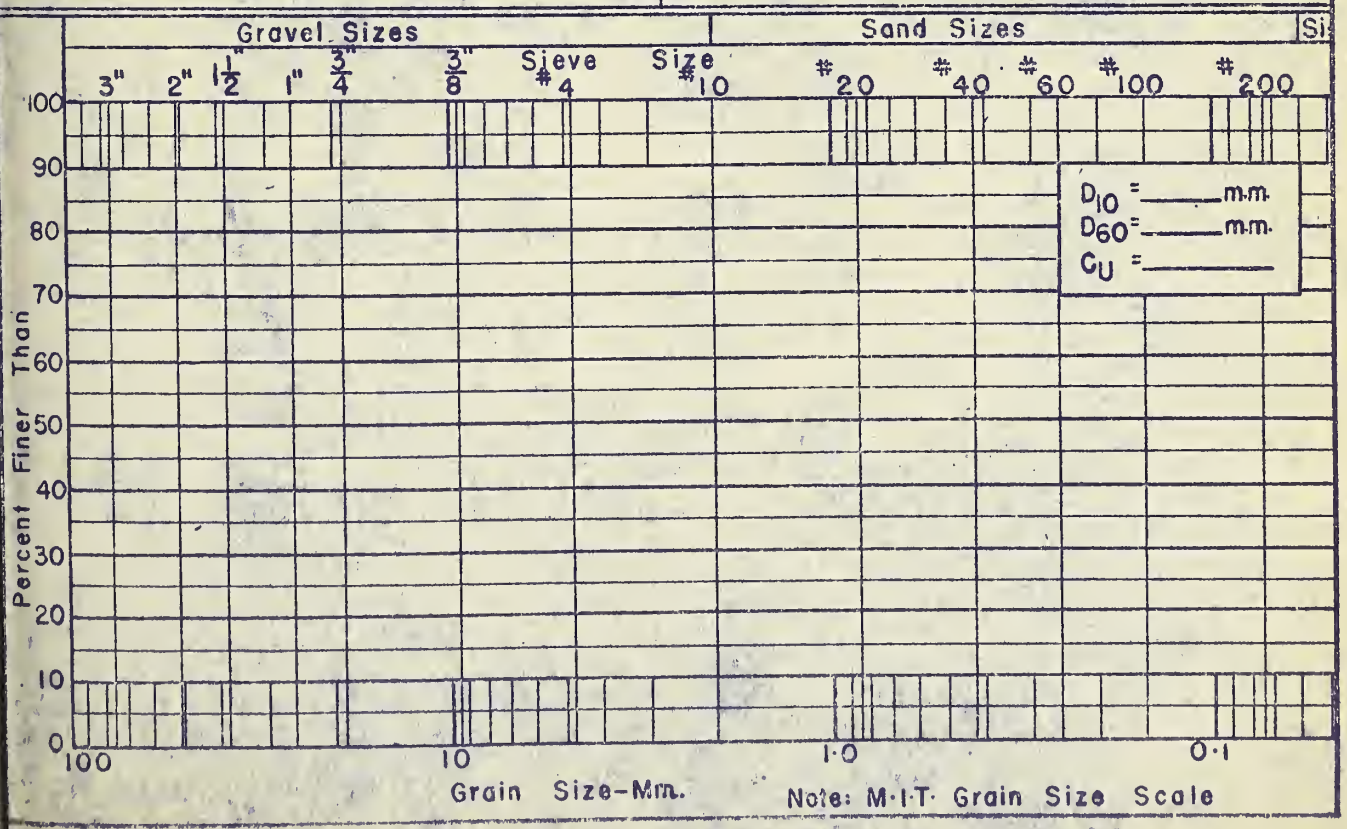
| Total Dry Weight of Sample | Sieve No. | Size of Opening Inches | Size of Opening Mm. | Weight Retained gms. | Total Wt. Finer Than gms. | Percent Finer Than | % Finer Than Basis Orig. Sample |
|---|---|---|---|---|---|---|---|
| Initial Dry Weight Retained No. 4 | | | | | | | |
| Tare No. | | | | | | | |
| Wt. Dry + Tare | | | | | | | |
| Tare | | 3/4 | 19.10 | | | | |
| Wt. Dry | | 3/8 | 9.52 | | | | |
| | 4 | .185 | 4.76 | | | | |
| Passing | 4 | | | | | | |
| Initial Dry Weight | | | | | AAA.35 | | Ind. % Ret |
| Passing No. 4 | 10 | .079 | 2.000 | 396.03 | A8.32 | 10.9 | 89.1 |
| Tare No. 1 | 20 | .0331 | .840 | 34.25 | 14.07 | | |
| Wt. Dry + Tare 651.35 | 40 | .0165 | .420 | 0.29 | 13.78 | 3.1 | 96.9 |
| Tare 207.00 | 60 | .0097 | .250 | 0.30 | 13.48 | | |
| Wt. Dry AAA.35 | 100 | .0059 | .149 | 0.52 | 12.96 | | |
| | 200 | .0029 | .074 | 1.19 | 11.77 | 2.6 | 97.4 |
| Passing | 200 | | | | | | |

Description of Sample

Time of Sieving

Method of Preparation
Fraction washed over #200 sieve.

Remarks


Gravel Sizes
Sand Sizes
Sieve Size
3" 2" 1½" 1" ¾" ⅜" #4 #10 #20 #40 #60 #100 #200
100 90 80 70 60 50 40 30 20 10 0
Percent Finer Than
D10 = ____ m.m.
D60 = ____ m.m.
CU = ____
100 10 1.0 0.1
Grain Size-Mm.
Note: M.I.T. Grain Size Scale

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SOIL MECHANICS LABORATORY
## SIEVE ANALYSIS

PROJECT Permeability Investigation
SITE Crawford Pit
SAMPLE Stock – #10 + #40 Fraction
LOCATION
HOLE DEPTH
TECHNICIAN TSC DATE 6-8-59

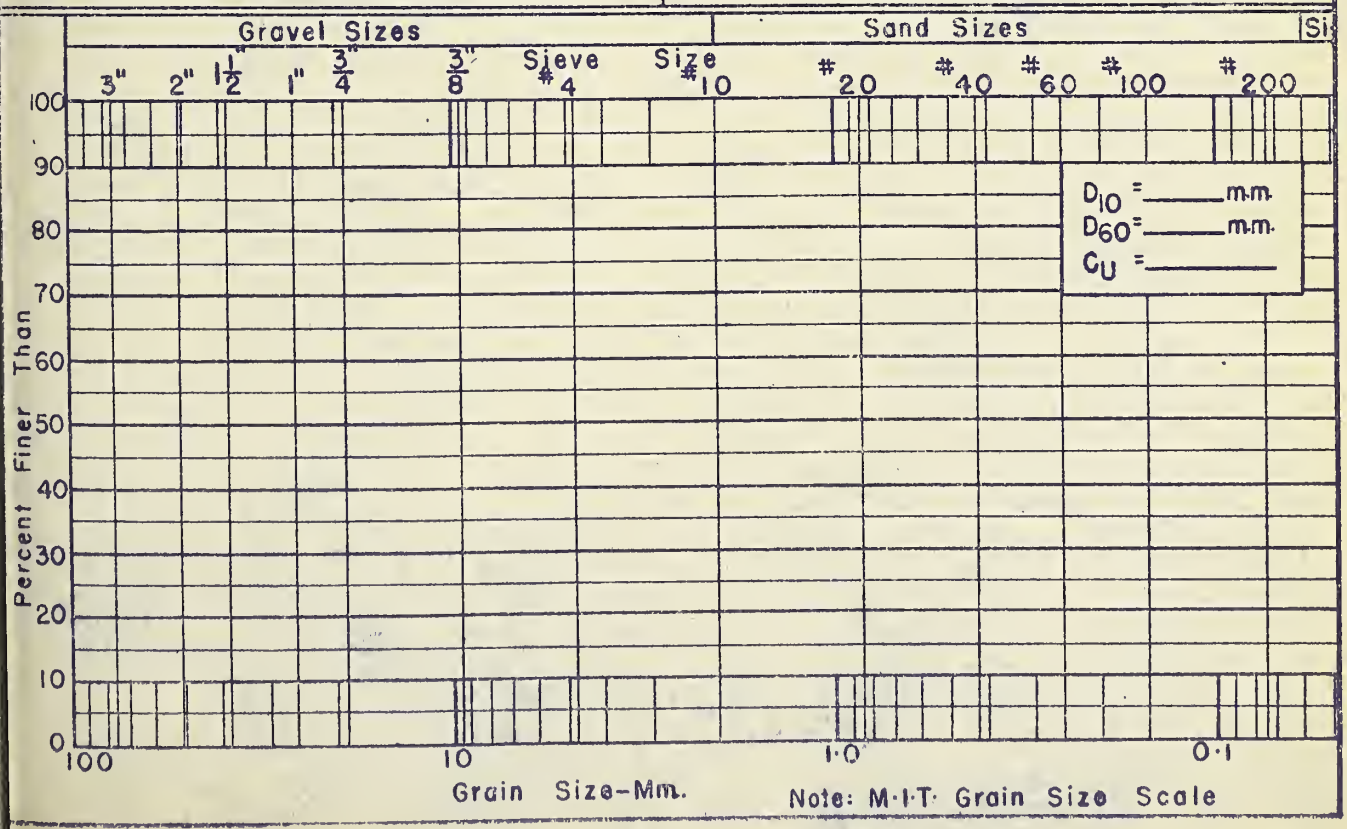
| Total Dry Weight of Sample | Sieve No. | Size of Opening Inches | Size of Opening Mm. | Weight Retained gms. | Total Wt. Finer Than gms. | Percent Finer Than | % Finer Than Basis Orig. Sample |
|---|---|---|---|---|---|---|---|
| Initial Dry Weight Retained No. 4 | | | | | | | |
| Tare No. | | | | | | | |
| Wt. Dry + Tare | | | | | | | |
| Tare | | 3/4 | 19.10 | | | | |
| Wt. Dry | | 3/8 | 9.52 | | | | |
| | 4 | .185 | 4.76 | | | | |
| Passing | 4 | | | | | | |
| Initial Dry Weight Passing No. 4 | | | | | | | Ind. % Ret |
| | 10 | .079 | 2.000 | | 493.04 | | |
| Tare No. #2 | 20 | .0331 | .840 | 264.19 | 228.85 | 46.4 | |
| Wt. Dry + Tare 715.74 | 40 | .0165 | .420 | 133.03 | 95.82 | 19.4 | 80.6 |
| Tare 222.70 | 60 | .0097 | .250 | 21.07 | 74.75 | 15.1 | |
| Wt. Dry 493.04 | 100 | .0059 | .149 | 5.76 | 68.99 | 14.0 | |
| | 200 | .0029 | .074 | 7.75 | 61.24 | 12.4 | 87.6 |
| Passing | 200 | | | | | | |

Description of Sample

Time of Sieving

Method of Preparation
Fraction washed over #200 Sieve.

Remarks


Gravel Sizes
Sand Sizes
Sieve Size
3" 2" 1½" 1" ¾" ⅜" #4 #10 #20 #40 #60 #100 #200
100 90 80 70 60 50 40 30 20 10 0
Percent Finer Than
D10 = ____ m.m.
D60 = ____ m.m.
CU = ____
100 10 1.0 0.1
Grain Size-Mm.
Note: M.I.T. Grain Size Scale

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# SIEVE ANALYSIS

PROJECT Permeability Investigation.
SITE Crawford Pit
SAMPLE Stock - #40 Fraction
LOCATION
HOLE DEPTH
TECHNICIAN T.-I DATE 6-8-59

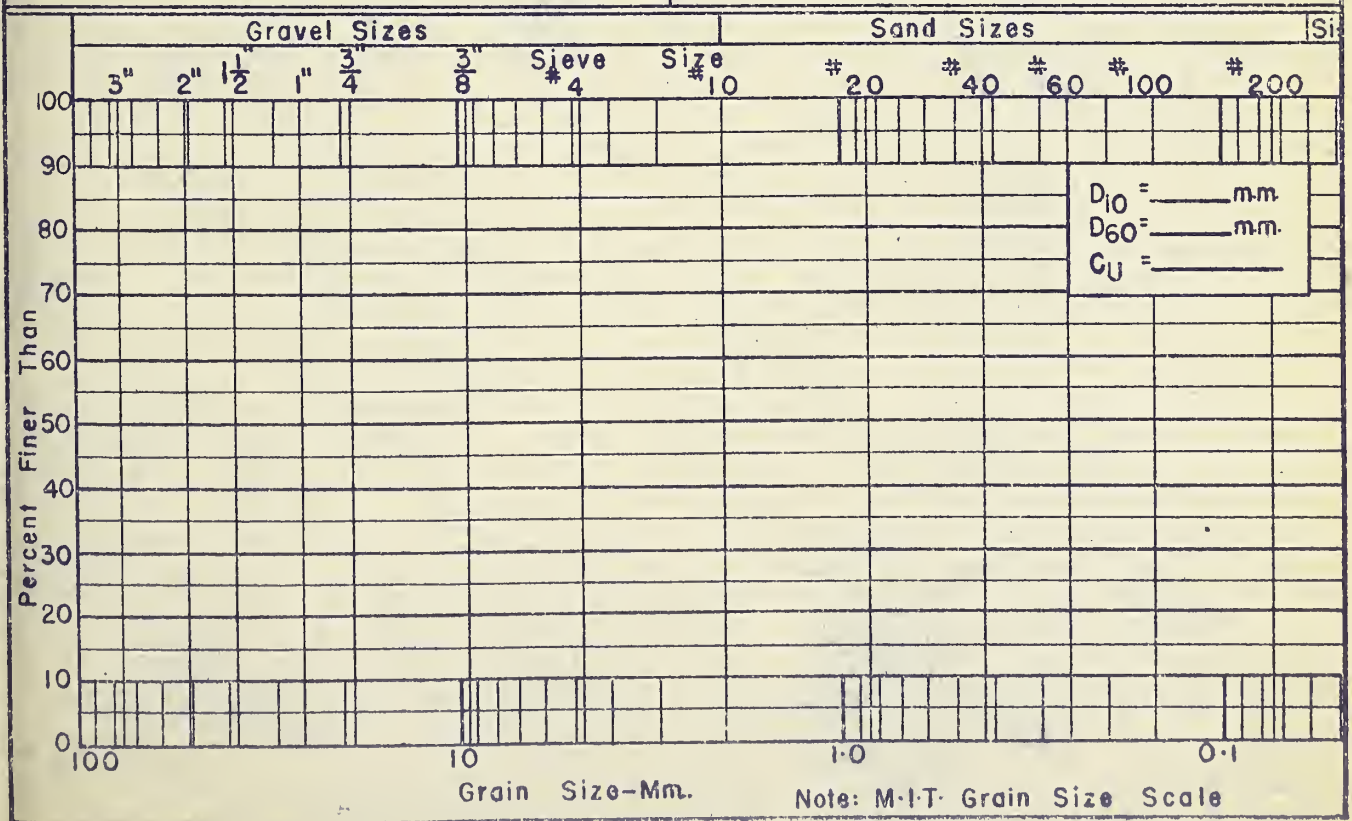
| Total Dry Weight of Sample | Sieve No. | Size of Opening Inches | Size of Opening Mm. | Weight Retained gms. | Total Wt. Finer Than gms. | Percent Finer Than | % Finer Than Basis Orig. Sample |
|---|---|---|---|---|---|---|---|
| Initial Dry Weight Retained No. 4 | | | | | | | |
| Tare No. | | | | | | | |
| Wt. Dry + Tare | | | | | | | |
| Tare | | 3/4 | 19.10 | | | | |
| Wt. Dry | | 3/8 | 9.52 | | | | |
| | 4 | .185 | 4.76 | | | | |
| Passing | 4 | | | | | | |
| Initial Dry Weight Passing No. 4 | | | | | | | Ind. % Ret. |
| | 10 | .079 | 2.000 | | | | |
| Tare No. #3 | 20 | .0331 | .840 | | | | |
| Wt. Dry + Tare 663.75 | 40 | .0165 | .420 | | 444.95 | | |
| Tare 218.80 | 60 | .0097 | .250 | 71.48 | 373.47 | 84.0 | |
| Wt. Dry 444.95 | 100 | .0059 | .149 | 79.23 | 294.24 | 66.2 | |
| | 200 | .0029 | .074 | 76.98 | 217.26 | 48.4 | 51.6 |
| Passing | 200 | | | | | | |

Description of Sample

Time of Sieving

Method of Preparation
Fraction washed over #200 sieve.

Remarks


Gravel Sizes
Sand Sizes
Sieve Size
3" 2" 1½" 1" ¾" ⅜" #4 #10 #20 #40 #60 #100 #200
100 90 80 70 60 50 40 30 20 10 0
Percent Finer Than
D10 = ____ m.m.
D60 = ____ m.m.
CU = ____
100 10 1.0 0.1
Grain Size-Mm.
Note: M.I.T. Grain Size Scale

UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

# SPECIFIC GRAVITY

PROJECT Permeability Investigation
SITE Crawford Pit Gravel
SAMPLE
LOCATION
HOLE DEPTH
TECHNICIAN TSN DATE 4-8-59

| | | |
|---|---|---|
| Sample No. | - #4 Material | |
| Flask No. | #2 | |
| Method of Air Removal | -0.83 Kg/cm² for 30 Min | |
| $W_{b+w+s}$ | 738.88 | |
| Temperature T °C | 23.5 | |
| $W_{b+w}$ | 673.23 | |
| Evaporating Dish No. | #1 | |
| Wt. Sample Dry + Dish | 279.64 | |
| Tare Dish | 175.13 | |
| $W_s$ | 104.51 | |
| $G_s$ | 2.69 | |

$W_{b+w+s}$ = Weight of flask + water + sample at T°.
$W_{b+w}$ = Weight of flask + water at T° (flask calibration curve).
$W_s$ = Weight of dry soil
$G_s$ = Specific gravity of soil particles = $\frac{W_s}{W_s + W_{b+w} - W_{b+w+s}}$

Determination of $W_s$ from wet soil sample:

| | | | | | |
|---|---|---|---|---|---|
| Sample No. | | | Sample No. | | |
| Container No. | | | Container No. | | |
| Wt. Sample Wet + Tare | | | Wt. Test Sample Wet + Tare | | |
| Wt. Sample Dry + Tare | | | Tare Container | | |
| Wt. Water | | | Wt. Test Sample Wet | | |
| Tare Container | | | $W_s$ | | |
| Wt. of Dry Soil | | | | | |
| Moisture Content $w$ % | | | | | |

Description of Sample: Crawford Pit Gravel (-3" + #4)

Wt Sample SSD + tare = 2923.5
Wt of Tare = 381.9 Bulk Sp. Gr. = $\frac{B}{B-C}$ = 2.62
Wt. of Sample SSD = 2541.6
App. Sp. Gr. $\frac{A}{A-C}$ = 2.67

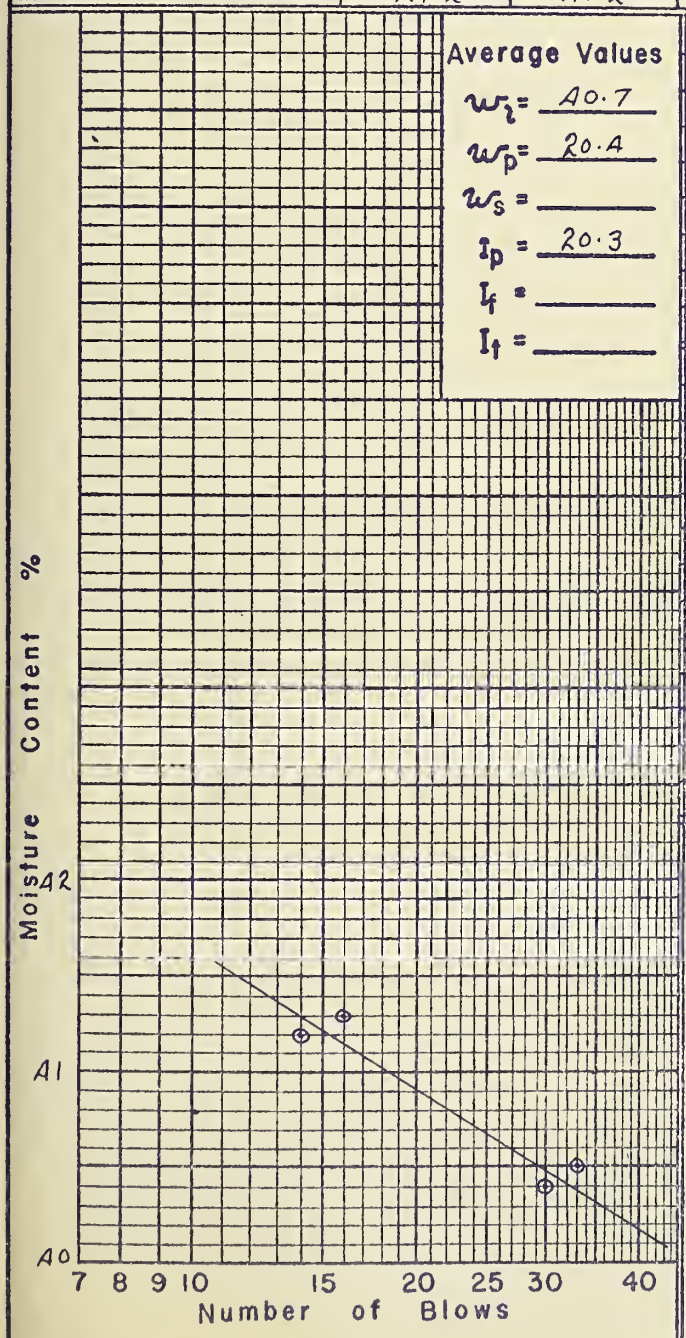
Remarks: Wt. Sample + Basket in water = 1869.7
Wt. Basket in water = 300.6 Ave Sp. Gr of
Wt. Sample in water = 1569.1 Combined Aggregate
Wt. Sample oven dry + tare = 2891.3 = 2.66
Wt. Tare = 381.9
Wt. Sample oven dry = 2509.4

# UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Permeability Investigation
SITE Crawford Pit
SAMPLE Stock - #40 Fraction
LOCATION
HOLE DEPTH
TECHNICIAN T.S.L. DATE 5-8-59

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 14 | 14 | 16 | 33 | 30 | 30 |
| Container No. | V72 | VA2 | V9 | V73 | V7 | V6 |
| Wt. Sample Wet + Tare | 87.41 | 87.20 | 97.47 | 80.45 | 86.74 | 92.37 |
| Wt. Sample Dry + Tare | 82.33 | 81.40 | 92.23 | 76.36 | 81.68 | 87.89 |
| Wt. Water | 5.08 | 5.78 | 5.24 | 4.09 | 5.06 | 4.48 |
| Tare Container | 70.00 | 67.38 | 79.58 | 66.28 | 69.16 | 76.78 |
| Wt. of Dry Soil | 12.33 | 14.04 | 12.65 | 10.08 | 12.52 | 11.11 |
| Moisture Content w% | 41.2 | 41.2 | 41.3 | 40.5 | 40.4 | 40.4 |




**Average Values**

$w_l$ = 40.7
$w_p$ = 20.4
$w_s$ = ____
$I_p$ = 20.3
$I_f$ = ____
$I_t$ = ____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | BE | AE | AH |
| Wt. Sample Wet+Tare | 63.020 | 59.322 | 58.751 |
| Wt. Sample Dry+Tare | 61.561 | 58.263 | 57.620 |
| Wt. Water | 1.459 | 1.059 | 1.131 |
| Tare Container | 54.381 | 53.087 | 52.057 |
| Wt. of Dry Soil | 7.180 | 5.176 | 5.563 |
| Moisture Content % | 20.3 | 20.4 | 20.4 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content w% | | | |
| Vol. Container V | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

Remarks: ____

## Mix Design Computations - Crawford Pit Material

| Sieve Size | 3" | 1½ | 3/4 | 3/8 | No.4 | No.10 | No.40 | No.200 |
|---|---|---|---|---|---|---|---|---|
| Clark's Grdg. % Pass. | 100 | 90 | 73 | -- | 40 | 25 | 14.0 | 8.9 |
| Millions' Grdg. % Pass. | 100 | 93 | 75 | -- | 43 | 29 | 17.0 | 11.2 |
| Computed Grading Used, % Passing | 100 | 93 | 75 | 56 | 43 | 30 | 19.6 | 10.0 |
| Batch Wts. (Kg) | 0 | 2.38 | 6.14 | 6.47 | 4.43 | 4.77 | 4.08 | 6.00 |
| Batch Wts. Adjusted for Hygroscopic MC | 0 | 2.38 | 6.14 | 6.47 | 4.43 | 4.80 | 4.17 | 6.22 |

# APPENDIX D

## Analysis of Sieved Fractions of Winger Pit Material Used in the Permeability Tests

UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

# MOISTURE CONTENT

PROJECT Permeability Investigation
SITE Winger Pit
SAMPLE Sieved Stock Fractions
LOCATION
HOLE DEPTH .
TECHNICIAN TSL DATE

| ~~Hole No.~~ Fraction | -3" + #4 | -#4 + #10 | -#10 + #40 | -#40 | | |
|---|---|---|---|---|---|---|
| Depth | | | | | | |
| Sample No. | 1 | 2 | 3 | 4 | | |
| Container No. | B | P1 | P2 | 3 | | |
| Wt. Sample Wet + Tare | 4472.5 | 606.50 | 575.00 | 386.83 | | |
| Wt. Sample Dry + Tare | 4464.3 | 602.72 | 571.10 | 384.40 | | |
| Wt. Water | 8.2 | 3.78 | 3.90 | 2.43 | | |
| Tare Container | 381.9 | 205.48 | 213.30 | 205.52 | | |
| Wt. of Dry Soil | 4082.4 | 397.24 | 357.80 | 178.88 | | |
| Moisture Content $w$ % | 0.20 | 0.95 | 1.09 | 1.36 | | |

| Hole No | | | | | | |
|---|---|---|---|---|---|---|
| Depth | | | | | | |
| Sample No. | | | | | | |
| Container No | | | | | | |
| Wt. Sample Wet + Tare | | | | | | |
| Wt. Sample Dry + Tare | | | | | | |
| Wt. Water | | | | | | |
| Tare Container | | | | | | |
| Wt. of Dry Soil | | | | | | |
| Moisture Content $w$ % | | | | | | |

| Hole No. | | | | | | |
|---|---|---|---|---|---|---|
| Depth | | | | | | |
| Sample No. | | | | | | |
| Container No. | | | | | | |
| Wt. Sample Wet + Tare | | | | | | |
| Wt. Sample Dry + Tare | | | | | | |
| Wt. Water | | | | | | |
| Tare Container | | | | | | |
| Wt. of Dry Soil | | | | | | |
| Moisture Content $w$% | | | | | | |

Remarks:

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DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
# SIEVE ANALYSIS

PROJECT Permeability Investigation
SITE Winger Pit
SAMPLE Stock - #4 + #10 Fraction
LOCATION
HOLE DEPTH
TECHNICIAN TSL DATE 5-8-59

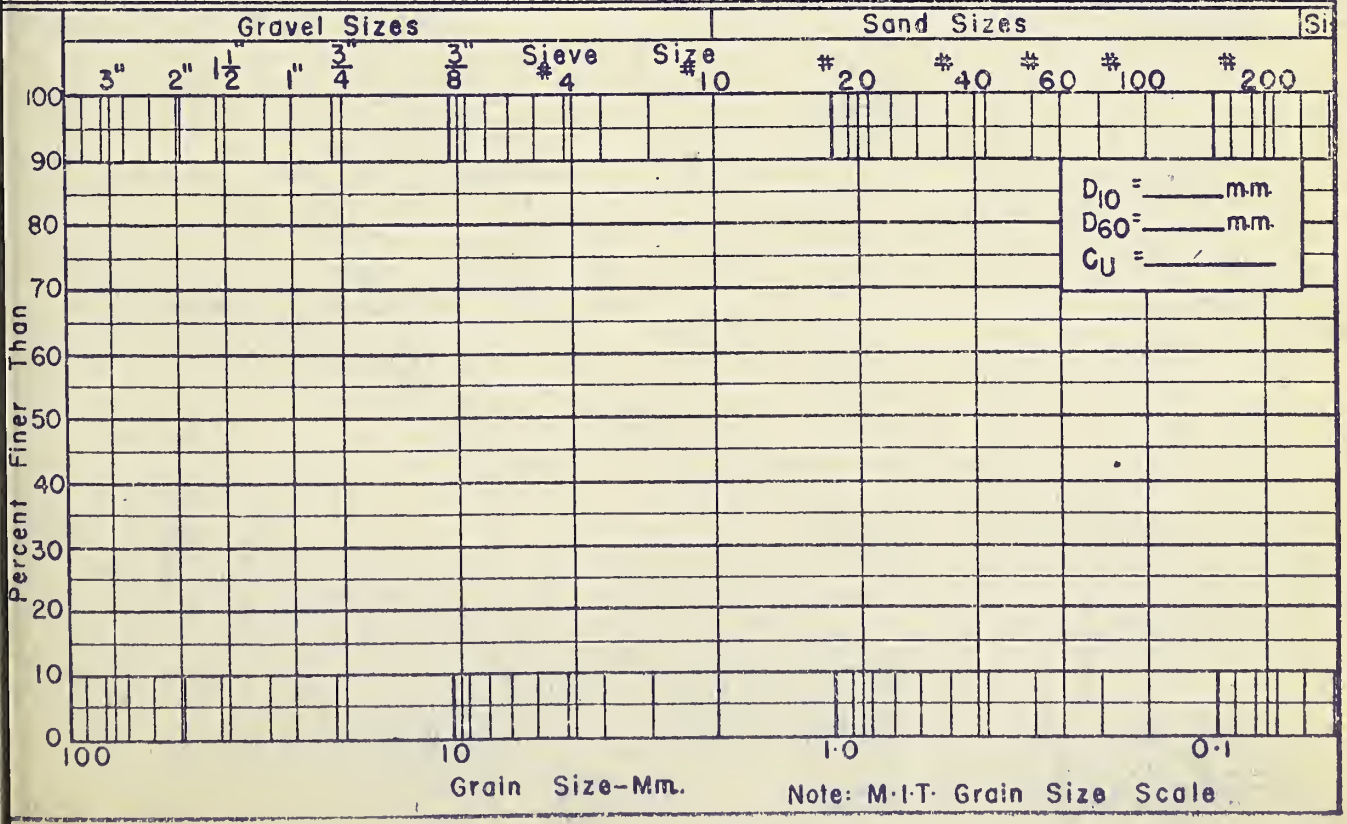
| Total Dry Weight of Sample | Sieve No. | Size of Opening Inches | Size of Opening Mm. | Weight Retained gms. | Total Wt. Finer Than gms. | Percent Finer Than | % Finer Than Basis Orig. Sample |
|---|---|---|---|---|---|---|---|
| Initial Dry Weight | | | | | | | |
| Retained No. 4 | | | | | | | |
| Tare No. | | | | | | | |
| Wt. Dry + Tare | | | | | | | |
| Tare | | 3/4 | 19.10 | | | | |
| Wt. Dry | | 3/8 | 9.52 | | | | |
| | 4 | .185 | 4.76 | | | | |
| Passing | 4 | | | | | | |
| Initial Dry Weight | | | | | 388.86 | | Ind. % Ret |
| Passing No. 4 | 10 | .079 | 2.000 | 221.52 | 167.34 | 43.1 | 56.9 |
| Tare No. #3 | 20 | .0331 | .840 | 30.48 | 136.86 | 35.2 | |
| Wt. Dry + Tare 594.34 | 40 | .0165 | .420 | 3.71 | 133.15 | 34.2 | 8.9 |
| Tare 205.48 | 60 | .0097 | .250 | 3.23 | 129.92 | 33.4 | |
| Wt. Dry 388.86 | 100 | .0059 | .149 | 3.20 | 126.72 | 32.6 | |
| | 200 | .0029 | .074 | 7.32 | 119.40 | 30.7 | 3.5 |
| Passing | 200 | | | | | | Pan. 30.7 |

Description of Sample

Time of Sieving

Method of Preparation
Fraction Washed over #200 Sieve

Remarks


Gravel Sizes
Sand Sizes
Sieve Size
3" 2" 1½" 1" ¾" ⅜" #4 #10 #20 #40 #60 #100 #200
100 90 80 70 60 50 40 30 20 10 0
Percent Finer Than
$D_{10}$ = ____ m.m.
$D_{60}$ = ____ m.m.
$C_U$ = ____
100 10 1.0 0.1
Grain Size-Mm.
Note: M.I.T. Grain Size Scale

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# SIEVE ANALYSIS

PROJECT Permeability Investigation
SITE Winger Pit
SAMPLE Slock - #10 + #40 Fraction
LOCATION
HOLE DEPTH
TECHNICIAN TS-1. DATE

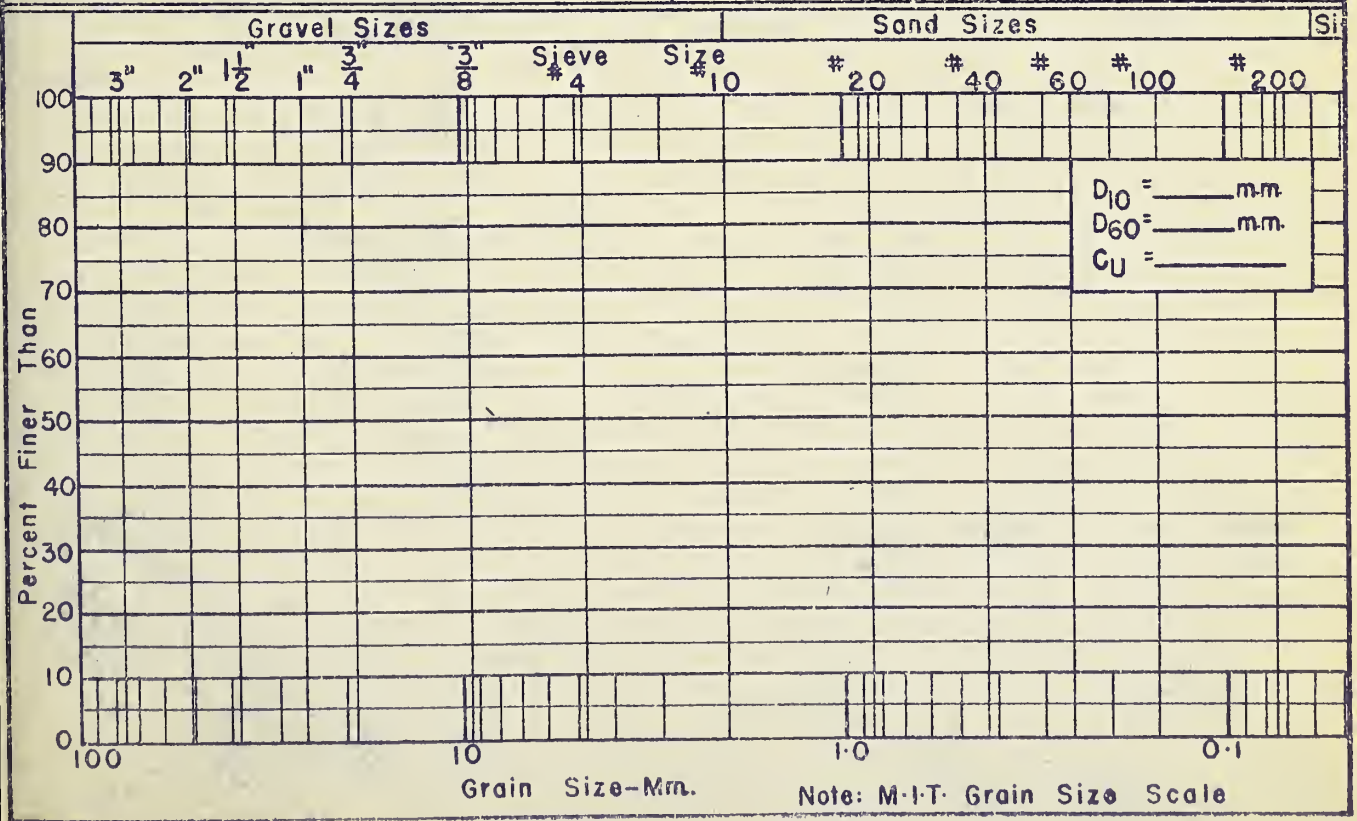
| Total Dry Weight of Sample | Sieve No. | Size of Opening Inches | Size of Opening Mm. | Weight Retained gms. | Total Wt. Finer Than gms. | Percent Finer Than | % Finer Than Basis Orig. Sample |
|---|---|---|---|---|---|---|---|
| Initial Dry Weight Retained No. 4 | | | | | | | |
| Tare No. | | | | | | | |
| Wt. Dry + Tare | | | | | | | |
| Tare | | 3/4 | 19.10 | | | | |
| Wt. Dry | | 3/8 | 9.52 | | | | |
| | 4 | .185 | 4.76 | | | | |
| Passing | 4 | | | | | | |
| Initial Dry Weight Passing No. 4 | | | | | | | Ind. % Ret. |
| | 10 | .079 | 2.000 | | 345.38 | | |
| Tare No. #2 | 20 | .0331 | .840 | 77.49 | 267.89 | 77.5 | |
| Wt. Dry + Tare 558.68 | 40 | .0165 | .420 | 114.31 | 153.58 | 44.5 | 55.5 |
| Tare 213.30 | 60 | .0097 | .250 | 46.65 | 106.93 | 30.9 | |
| Wt. Dry 345.38 | 100 | .0059 | .149 | 6.00 | 100.93 | 29.2 | |
| | 200 | .0029 | .074 | 7.10 | 93.83 | 27.2 | 72.8 |
| Passing | 200 | | | | | | |

Description of Sample

Time of Sieving

Method of Preparation
Fraction Washed over #200 Sieve

Remarks


Gravel Sizes
Sand Sizes
Sieve Size
3" 2" 1½" 1" ¾" ⅜" #4 #10 #20 #40 #60 #100 #200
100 90 80 70 60 50 40 30 20 10 0
Percent Finer Than
D10 = ____ m.m.
D60 = ____ m.m.
CU = ____
100 10 1.0 0.1
Grain Size-Mm.
Note: M.I.T. Grain Size Scale

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SOIL MECHANICS LABORATORY
## SIEVE ANALYSIS

PROJECT Permeability Investigation
SITE Winger Pit
SAMPLE Stock – #40 Fraction
LOCATION
HOLE DEPTH
TECHNICIAN T.S.-L. DATE 9-8-59

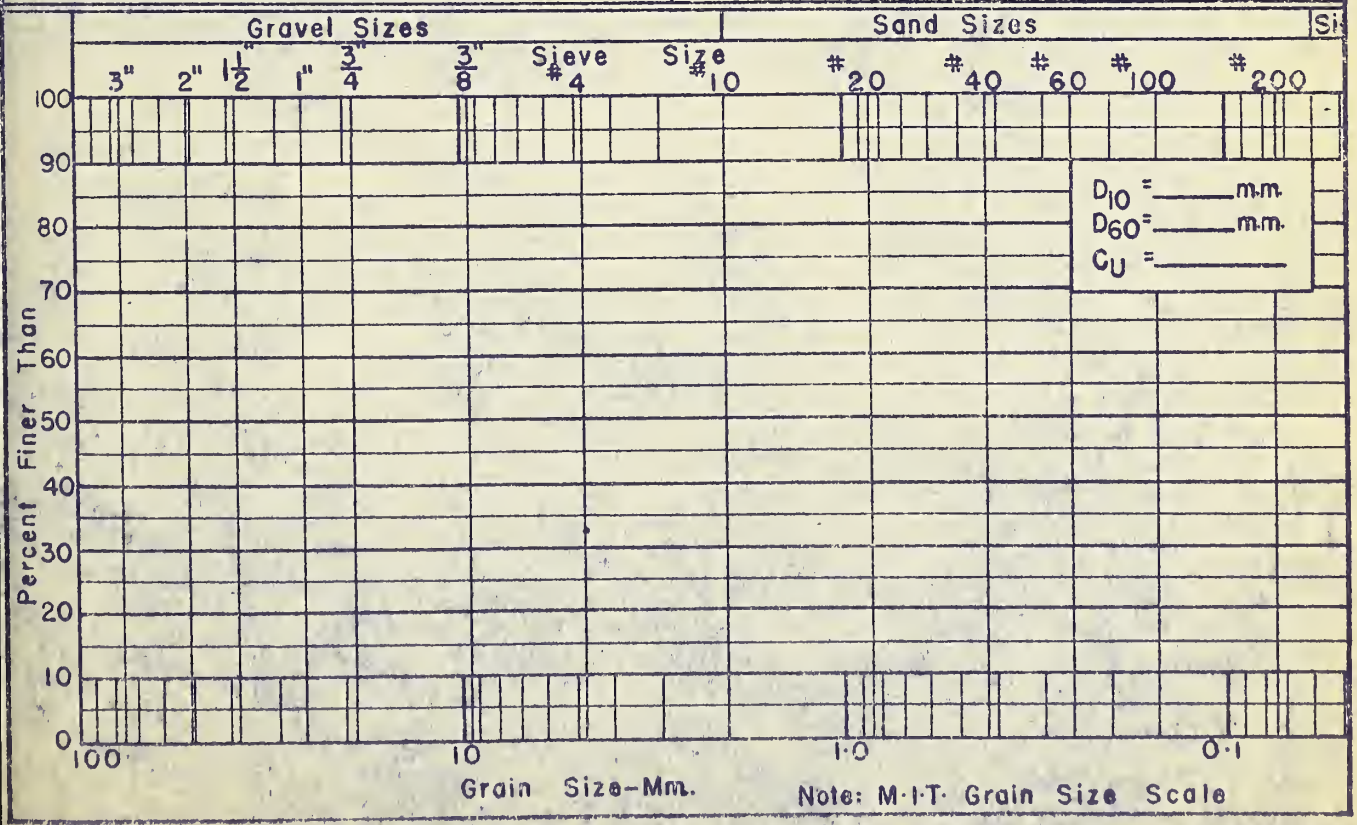
| Total Dry Weight of Sample | Sieve No. | Size of Opening Inches | Size of Opening Mm. | Weight Retained gms. | Total Wt. Finer Than gms. | Percent Finer Than | % Finer Than Basis Orig. Sample |
|---|---|---|---|---|---|---|---|
| Initial Dry Weight Retained No. 4 | | | | | | | |
| Tare No. | | | | | | | |
| Wt. Dry + Tare | | | | | | | |
| Tare | | 3/4 | 19.10 | | | | |
| Wt. Dry | | 3/8 | 9.52 | | | | |
| | 4 | .185 | 4.76 | | | | |
| Passing | 4 | | | | | | |
| Initial Dry Weight Passing No. 4 | | | | | | | Ind. % Ret. |
| | 10 | .079 | 2.000 | | | | |
| Tare No. #3 | 20 | .0331 | .840 | | | | |
| Wt. Dry + Tare 379.05 | 40 | .0165 | .420 | | 173.50 | | |
| Tare 205.55 | 60 | .0097 | .250 | 40.93 | 132.57 | 76.4 | |
| Wt. Dry 173.50 | 100 | .0059 | .149 | 27.99 | 104.58 | 60.4 | |
| | 200 | .0029 | .074 | 20.32 | 84.26 | 48.6 | 51.4 |
| Passing | 200 | | | | | | |

Description of Sample

Time of Sieving

Method of Preparation
Fraction washed over #200 sieve

Remarks This material is the final –#40 blend used in the permeability investigation.


Gravel Sizes
Sand Sizes
Sieve Size
3" 2" 1½" 1" ¾" ⅜" #4 #10 #20 #40 #60 #100 #200
100 90 80 70 60 50 40 30 20 10 0
Percent Finer Than
$D_{10}$ = ____ m.m.
$D_{60}$ = ____ m.m.
$C_U$ = ____
100 10 1.0 0.1
Grain Size–Mm.
Note: M.I.T. Grain Size Scale

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SOIL MECHANICS LABORATORY

# SPECIFIC GRAVITY

PROJECT Permeability Investigation
SITE Winger Pit Gravel
SAMPLE
LOCATION
HOLE DEPTH
TECHNICIAN T.S.L. DATE 4-8-59

| | | |
|---|---|---|
| Sample No. | -#4 Material | |
| Flask No. | #2 | |
| Method of Air Removal | -0.83 Kg/cm² for 30 Min | |
| $W_{b+w+s}$ | 712.02 | |
| Temperature T °C | 22.4 | |
| $W_{b+w}$ | 673.32 | |
| Evaporating Dish No. | #4 | |
| Wt. Sample Dry + Dish | 269.40 | |
| Tare Dish | 207.80 | |
| $W_s$ | 61.60 | |
| $G_s$ | 2.69 | |

$W_{b+w+s}$ = Weight of flask + water + sample at T°.
$W_{b+w}$ = Weight of flask + water at T° (flask calibration curve).
$W_s$ = Weight of dry soil
$G_s$ = Specific gravity of soil particles = $\frac{W_s}{W_s + W_{b+w} - W_{b+w+s}}$

Determination of $W_s$ from wet soil sample:

| | | | | | |
|---|---|---|---|---|---|
| Sample No. | | | Sample No. | | |
| Container No. | | | Container No. | | |
| Wt. Sample Wet + Tare | | | Wt. Test Sample Wet + Tare | | |
| Wt. Sample Dry + Tare | | | Tare Container | | |
| Wt. Water | | | Wt. Test Sample Wet | | |
| Tare Container | | | $W_s$ | | |
| Wt. of Dry Soil | | | | | |
| Moisture Content $w$ % | | | | | |

Description of Sample: Winger Pit Gravel (-3" + #4)

Wt. Sample SSD + Tare = 2927.5

Wt tare 381.9 Bulk sp. Gr. $\frac{B}{B-C}$ = 2.62

(B) Wt Sample SSD 2545.6

App. Sp. Gr. $\frac{A}{A-C}$ = 2.67

Remarks: Wt. Sample sat. in water + Basket = 1873.8

Wt Basket in water = 300.6 Ave. Sp. Gr. of

(C) Wt. Sample in water = 1573.2 Combined Aggregate

Wt Sample oven dry + tare = 2895.3 = 2.66

Wt tare = 381.9

Wt Sample oven dry = 2513.4

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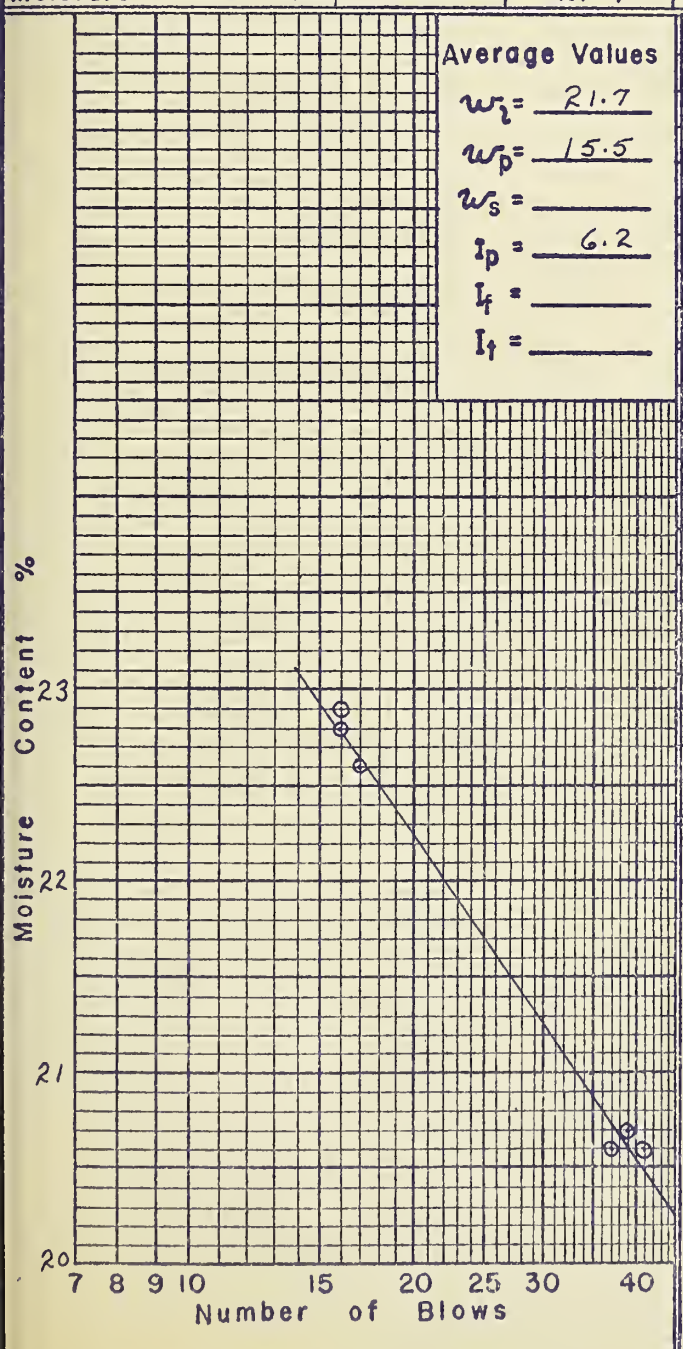
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
## ATTERBERG LIMITS

PROJECT Permeability Investigation
SITE Winger Pit
SAMPLE Stock – #40 Fraction.
LOCATION
HOLE DEPTH
TECHNICIAN T.S.W. DATE 10-9-59

### Liquid Limit

| Trial No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| No. of Blows | 16 | 16 | 17 | 37 | 39 | 41 |
| Container No. | V86 | V62 | V45 | V70 | V28 | V36 |
| Wt. Sample Wet + Tare | 98.38 | 86.91 | 92.45 | 107.98 | 108.07 | 91.15 |
| Wt. Sample Dry + Tare | 94.14 | 82.88 | 88.26 | 103.56 | 103.71 | 87.04 |
| Wt. Water | 4.24 | 4.03 | 4.19 | 4.42 | 4.36 | 4.11 |
| Tare Container | 75.50 | 65.05 | 69.69 | 82.18 | 82.70 | 67.04 |
| Wt. of Dry Soil | 18.64 | 17.83 | 18.57 | 21.48 | 21.01 | 20.00 |
| Moisture Content $w$% | 22.8 | 22.9 | 22.6 | 20.6 | 20.7 | 20.6 |




Average Values
$w_l$ = 21.7
$w_p$ = 15.5
$w_s$ = ____
$I_p$ = 6.2
$I_f$ = ____
$I_t$ = ____

### Plastic Limit

| Trial No. | 1 | 2 | 3 |
|---|---|---|---|
| Container No. | RB | BC | AV. |
| Wt. Sample Wet+Tare | 59.933 | 63.780 | 59.903 |
| Wt. Sample Dry+Tare | 59.125 | 62.410 | 59.158 |
| Wt. Water | 0.808 | 1.370 | 0.745 |
| Tare Container | 53.898 | 53.609 | 54.431 |
| Wt. of Dry Soil | 5.227 | 8.801 | 4.727 |
| Moisture Content % | 15.5 | 15.5 | 15.7 |

### Shrinkage Limit

| Trial No. | | | |
|---|---|---|---|
| Container No. | | | |
| Wt. Sample Wet + Tare | | | |
| Wt. Sample Dry + Tare | | | |
| Wt. Water | | | |
| Tare Container | | | |
| Wt. of Dry Soil $W_o$ | | | |
| Moisture Content $w$% | | | |
| Vol. Container $V$ | | | |
| Vol. Dry Soil Pat $V_o$ | | | |
| Shrinkage Vol. $V-V_o$ | | | |
| Shrinkage Limit $w_s$ | | | |

$$w_s = w\left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: ____

Remarks: ____

## Mix Design Computations - Winger Pit Material

| Sieve Size | 3" | 1½ | 3/4 | 3/8 | No.4 | No.10 | No.40 | No.200 |
|---|---|---|---|---|---|---|---|---|
| Average Pit Grading Dept. of Highways | 100 | 75 | 56 | -- | 36 | 31.5 | 26.2 | 14.4 |
| Million's Grd. | 100 | 73 | 56 | -- | 36 | 33.0 | 26.0 | 15.0 |
| Grading Used | 100 | 75 | 56 | -- | 36 | 31.5 | 26.0 | 14.1 |
| Batch Wts. in (kg) * | 100 | 9.10 | 6.90 | 4.37 | 2.91 | 2.90 | 3.04 | 7.31 |

* Corrected for Hygroscopic Moisture

# APPENDIX E

Analysis of the Feed Water Used in the Permeability Tests

C. EMERSON NOBLE
CHEMICAL ENGINEER
DIRECTOR INDUSTRIAL LABORATORIES
PROVINCIAL ANALYST

EDMONTON, ALBERTA
CANADA

August 26, 1959.

**WATER ANALYSIS REPORT**
**CHEMICAL**

Submitted by Mr. T.S.W. Harvey
Address Civil Engineering
University of Alberta
Container No.

Date received August 18, 1959.
Date reported
Source of Sample De-aired feed water
Serial No.
Lab. No. 59-6578

PARTS PER MILLION

Total Solids
Ignition Loss
Hardness
Sulphates
Chlorides
Alkalinity
Nature of Alkalinity
Nitrites
Nitrates
Iron
Fluorine

REMARKS:

Copper - 0.1 part per million
Zinc - faint trace
Cause of color could not be determined.

C. Emerson Noble,
Provincial Analyst.

CEN:mm

# APPENDIX F

Detailed Permeability Test Data and
Sample Computations for Part "B"

## PERMEABILITY DATA SHEET

Sample No. 1 — Initial Dry Density 119.6 #/ft$^3$

Material: Crawford Pit Natural — L/A - 2.50 x $10^{-2}$ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp. °C In | Temp. °C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. cm$^3$ | Effluent PH | Elaps. Time min Sec | Q cm$^3$/s | Q/HL cm$^2$/sec. | K' cm/sec | K cm/sec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7-7 | 1500 | - | - | 28° | | 53.25 | 51.00 | 2.25 | 5.72 | 1000 | - | 2-11 | 7.64 | 1.34 | $3.35\times10^{-2}$ | $2.78\times10^{-2}$ |
| " | 1510 | - | - | " | | - | - | 2.20 | 5.59 | 1000 | | 2-12 | 7.58 | 1.36 | $3.40\times10^{-2}$ | $2.80\times10^{-2}$ |
| " | 1530 | - | - | " | | - | - | 2.71 | 6.88 | 1000 | | 1-21 | 12.35 | 1.79 | $4.47\times10^{-2}$ | $3.69\times10^{-2}$ |
| " | 1543 | - | - | 27.9 | | - | - | 5.25 | 13.3 | 1000 | | 0-59.0 | 16.95 | 1.27 | $3.18\times10^{-2}$ | $2.62\times10^{-2}$ |
| " | 1600 | - | - | " | | - | - | 5.10 | 13.0 | 1000 | | 0-59.5 | 16.80 | 1.29 | $3.23\times10^{-2}$ | $2.67\times10^{-2}$ |
| " | 1606 | - | - | " | | - | - | 7.30 | 18.5 | 1000 | | 0-44.0 | 22.7 | 1.23 | $3.08\times10^{-2}$ | $2.54\times10^{-2}$ |
| " | 1608 | - | - | " | | - | - | 7.08 | 18.0 | 1000 | | 0-44.5 | 22.4 | 1.24 | $3.10\times10^{-2}$ | $2.56\times10^{-2}$ |
| | | | | -Permeameter shut off- | | | | | | | | | | | Ave = | $2.66\times10^{-2}$ |
| 12-7 | | | | Density = 125.1 #ft$^3$ | | | | L/A = $2.38\times10^{-2}$ | | | | | | | | |
| 12-7 | 1200 | - | - | 26.0 | | | | 38.7 | 98.2 | 50 | | 8-52 | .0940 | $9.56\times10^{-4}$ | $2.28\times10^{-5}$ | $1.98\times10^{-5}$ |
| " | 1210 | - | - | 26.0 | | | | 38.7 | 98.2 | 50 | | 8-52 | .0940 | $9.56\times10^{-4}$ | $2.28\times10^{-5}$ | $1.98\times10^{-5}$ |
| | | | | -Permeameter shut off- | | | | | | | | | | | | |

Note - Diff. Hds obtained by direct measurements

## PERMEABILITY DATA SHEET

Sample No. 1

Dry Density 124.2 #/ft$^3$

Material: Crawford Pit

L/A = $2.38 \times 10^{-2}$ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp. °C In | Temp. °C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. cm$^3$ | PH | Elaps. Time min Sec | Q cm$^3$/s | Q/HL cm$^2$/sec. | K' cm/sec | K cm/sec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12-7 | 1700 | - | - | 28.0 | - | (11.28"Hg) | | 154 | 390 | 1000 | - | 7-58 | 2.09 | $5.36 \times 10^{-3}$ | $1.27 \times 10^{-4}$ | $1.01 \times 10^{-4}$ |
| " | - | - | - | " | - | (11.20"Hg) | | 152 | 387 | 1000 | - | 9-20 | 1.79 | $4.62 \times 10^{-3}$ | $1.10 \times 10^{-4}$ | |
| 12-7 | 1730 | - | - | 28.0 | - | (23.00"Hg) | | 313 | 795 | 1000 | | 6-45 | 2.47 | $3.11 \times 10^{-3}$ | $7.30 \times 10^{-5}$ | $5.81 \times 10^{-4}$ |
| 12-7 | 1900 | - | - | 28.0 | - | (4.39"Hg) | | 59.7 | 152 | 50 | | 2-32 | 0.329 | $2.16 \times 10^{-3}$ | $5.15 \times 10^{-5}$ | $4.10 \times 10^{-5}$ |
| " | - | - | - | " | - | (4.39"Hg) | | 59.7 | 152 | 50 | | 2-42 | 0.308 | $2.03 \times 10^{-3}$ | $4.82 \times 10^{-5}$ | $3.84 \times 10^{-5}$ |
| 12-7 | 2215 | - | - | 27.9 | - | (22.5"Hg) | | 306 | 778 | 1000 | | 7-13 | 2.31 | $2.97 \times 10^{-3}$ | $7.06 \times 10^{-5}$ | $5.65 \times 10^{-5}$ |
| " | 2230 | - | - | " | - | (22.5"Hg) | | 306 | 778 | 1000 | | 8-04 | 2.07 | $2.66 \times 10^{-3}$ | $6.32 \times 10^{-5}$ | $5.25 \times 10^{-5}$ |
| 12-7 | 2242 | - | - | 27.9 | - | (59"Hg) | | 802 | 2040 | 1000 | | 5-50 | 2.86 | $1.40 \times 10^{-3}$ | $3.34 \times 10^{-5}$ | $2.78 \times 10^{-5}$ |

Note: The data shown above was obtained during the course of experiments with various instrumentation techniques and is not reliable due to sample disturbance caused by abrupt pressure changes.

## PERMEABILITY DATA SHEET

Sample No. 2 — Initial Dry Density 123.1 #/ft$^3$

Material: Crawford Pit — L/A = $2.66 \times 10^{-2}$ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp.°C In | Temp.°C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. $cm^3$ | Effluent PH | Elaps Time Min | Elaps Time Sec | Q $cm^3/s$ | $Q/H_L$ $cm^2/sec$ | K' cm/sec | K cm/sec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14-7 | 1325 | - | - | 25.0 | - | (0.80"Hg) | | 10.9 | 27.6 | 1000 | | 2 | 23 | 7.00 | 0.254 | $6.75 \times 10^{-3}$ | $5.97 \times 10^{-3}$ |
| " | 1328 | - | - | 25.0 | - | (0.80"Hg) | | 10.9 | 27.6 | 1000 | | 2 | 11 | 7.63 | 0.276 | $7.35 \times 10^{-3}$ | $6.52 \times 10^{-3}$ |
| " | 1333 | - | - | 25.0 | - | (0.80"Hg) | | 10.9 | 27.6 | 1000 | | 2 | 03 | 8.12 | 0.294 | $7.82 \times 10^{-3}$ | $6.93 \times 10^{-3}$ |
| " | 1336 | - | - | 25.0 | - | (1.00"Hg) | | 13.6 | 34.6 | 1000 | | 1 | 35 | 10.5 | 0.304 | $8.07 \times 10^{-3}$ | $7.16 \times 10^{-3}$ |
| " | 1340 | Flow Stopped- | | | | | | | | | | | | | | | |
| 14-7 | 1600 | - | - | 25.2 | | +7.00 | +1.00 | 6.00 | 15.2 | 1000 | | 2 | 22 | 7.05 | 0.464 | $1.23 \times 10^{-2}$ | $1.09 \times 10^{-2}$ |
| " | - | - | - | 25.2 | | +7.00 | +1.00 | 6.00 | 15.2 | 1000 | | 2 | 23 | 7.00 | 0.461 | $1.22 \times 10^{-2}$ | $1.08 \times 10^{-2}$ |
| " | 1630 | - | - | 25.2 | | +3.30 | -6.70 | 10.0 | 25.4 | 1000 | | 1 | 34 | 10.6 | 0.417 | $1.11 \times 10^{-2}$ | $0.98 \times 10^{-2}$ |
| | 1631 | Flow Stopped. | | | | | | | | | | | | | | | |
| 16-7 | 1100 | - | - | 25.0 | | - | - | 0.90 | 2.49 | 500 | | 7 | 00 | 1.19 | 0.477 | $1.27 \times 10^{-2}$ | $1.13 \times 10^{-2}$ |
| " | 1115 | - | - | 25.0 | | +18.03 | +15.10 | 2.93 | 7.45 | 1000 | | 4 | 30 | 3.70 | 0.497 | $1.32 \times 10^{-2}$ | $1.17 \times 10^{-2}$ |
| | 1200 | - | - | 25.0 | - | +15.28 | +8.48 | 6.80 | 17.3 | 1000 | | 2 | 13 | 7.55 | 0.436 | $1.16 \times 10^{-2}$ | $1.03 \times 10^{-2}$ |
| | - | - | - | 25.0 | - | +12.40 | +1.20 | 11.20 | 28.5 | 1000 | | 1 | 30 | 11.41 | 0.400 | $1.06 \times 10^{-2}$ | $9.40 \times 10^{-3}$ |
| | - | - | - | 25.0 | - | +6.50 | -12.20 | 18.70 | 47.5 | 1000 | | 0 | 58 | 17.2 | 0.362 | $9.63 \times 10^{-3}$ | $8.53 \times 10^{-3}$ |
| | 1300 | - | - | 25.0 | - | +2.10 | -15.20 | 17.30 | 44.0 | 1000 | | 1 | 03 | 15.9 | 0.361 | $9.60 \times 10^{-3}$ | $8.52 \times 10^{-3}$ |
| | 1400 | - | - | 25.0 | - | +1.30 | -15.70 | 17.00 | 43.2 | 1000 | | 1 | 04 | 15.6 | 0.361 | $9.60 \times 10^{-3}$ | $8.52 \times 10^{-3}$ |
| | 1500 | - | - | 25.0 | - | +10.65 | -9.30 | 19.95 | 50.7 | 1000 | | 0 | 54 | 18.5 | 0.364 | $9.70 \times 10^{-3}$ | $8.60 \times 10^{-3}$ |

## PERMEABILITY DATA SHEET

Sample No. 2 Sheet #2 Dry Density 128.3 #/ft$^3$

Material: Crawford Pit L/A = $2.55 \times 10^{-2}$ cm$^{-1}$

| Date | Time | Dial Rd. Start | Dial Rd. End | Temp.°C In | Temp.°C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. cm$^3$ | PH | Elaps. Time Min | Elaps. Time Sec | Q cm$^3$/s | $Q/H_L$ cm$^2$/sec. | K' cm/sec | K cm/sec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19-7 | 1650 | - | - | 25.4 | - | +29.8 | -21.5 | 51.3 | 130.0 | 1000 | - | 6 | 27 | 2.58 | $1.98 \times 10^{-2}$ | $5.05 \times 10^{-4}$ | $4.44 \times 10^{-4}$ |
| " | 1700 | - | - | 25.5 | - | +29.8 | -21.6 | 51.4 | 130.2 | 1000 | | 6 | 40 | 2.50 | $1.92 \times 10^{-2}$ | $4.90 \times 10^{-4}$ | $4.30 \times 10^{-4}$ |
| 20-7 | 0925 | - | - | 24.0 | - | +29.8 | -20.8 | 50.6 | 128.2 | 1000 | | 5 | 40 | 2.94 | $2.29 \times 10^{-2}$ | $5.85 \times 10^{-4}$ | $5.31 \times 10^{-4}$ |
| " | 0932 | - | - | 24.0 | | +29.8 | -21.3 | 51.1 | 129.8 | 1000 | | 6 | 07 | 2.72 | $2.10 \times 10^{-2}$ | $5.35 \times 10^{-4}$ | $4.86 \times 10^{-4}$ |
| " | 0948 | | | 24.0 | | +29.8 | -21.4 | 51.2 | 130.0 | 1000 | | 6 | 20 | 2.63 | $2.02 \times 10^{-2}$ | $5.15 \times 10^{-4}$ | $4.67 \times 10^{-4}$ |
| | - | - | - | 24.0 | | +29.8 | -21.5 | 51.3 | 130.1 | 1000 | | 6 | 28 | 2.58 | $1.97 \times 10^{-2}$ | $5.02 \times 10^{-4}$ | $4.55 \times 10^{-4}$ |
| | 1025 | - | - | 24.0 | | +29.8 | -21.7 | 51.5 | 130.8 | 1000 | | 7 | 04 | 2.36 | $1.81 \times 10^{-2}$ | $4.62 \times 10^{-4}$ | $4.20 \times 10^{-4}$ |

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## PERMEABILITY DATA SHEET

Sample No. 3 - Sheet #1 — Initial Dry Density 127.0 #/ft$^3$

Material: Crawford Pit — L/A = $2.65 \times 10^{-2}$ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp.°C In | Temp.°C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. cm$^3$ | Effluent PH | Elaps. Time Min | Elaps. Time Sec | Q cm$^3$/s | Q/$H_L$ cm$^2$/sec. | K' cm/sec | K cm/sec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21-7 | 1500 | - | - | - 24.8 | | +29.8 | -22.7 | 52.5 | 133.5 | 1000 | - | 11 | 52 | 1.41 | $1.06 \times 10^{-2}$ | $2.81 \times 10^{-4}$ | $2.59 \times 10^{-4}$ |
| " | 1515 | - | - | - 25.0 | | +29.8 | -22.7 | 52.5 | 133.5 | 1000 | | 11 | 52 | 1.41 | $1.06 \times 10^{-2}$ | $2.81 \times 10^{-4}$ | $2.58 \times 10^{-4}$ |
| " | 1615 | - | - | - 25.0 | | +29.8 | -22.9 | 52.7 | 134.0 | 1000 | | 12 | 52 | 1.30 | $9.70 \times 10^{-3}$ | $2.57 \times 10^{-4}$ | $2.28 \times 10^{-4}$ |
| " | 1630 | Outlet valve closed. Sample standing under Head. | | | | | | | | | | | | | | | |
| 25-7 | 1000 | - | - | - 24.8 | | +29.8 | -22.8 | 52.6 | 133.5 | 1000 | | 12 | 01 | 1.39 | $1.04 \times 10^{-2}$ | $2.75 \times 10^{-4}$ | $2.46 \times 10^{-4}$ |
| " | 1100 | - | - | - 24.8 | | +29.8 | -23.0 | 52.8 | 134.0 | 1000 | | 14 | 45 | 1.03 | $8.44 \times 10^{-3}$ | $2.24 \times 10^{-4}$ | $2.00 \times 10^{-4}$ |
| | | Note: Flow of approx. 1.4 cm$^3$/sec maintained from 1300 hours to 1645 hrs. at a total pressure of 17 psi. Head loss unknown. | | | | | | | | | | | | | | | |
| 25-7 | 1645 | - | - | - 25.0 | | +30.3 | -23.5 | 53.8 | 136.8 | 1000 | | 8 | 07 | 2.06 | $1.50 \times 10^{-2}$ | $3.98 \times 10^{-4}$ | $3.53 \times 10^{-4}$ |
| | 1655 | - | - | - 25.0 | | +30.3 | -23.7 | 53.9 | 137. | 1000 | | 8 | 43 | 1.91 | $1.39 \times 10^{-2}$ | $3.70 \times 10^{-4}$ | $3.28 \times 10^{-4}$ |
| | 1715 | Outlet valve closed. Sample standing under Head | | | | | | | | | | | | | | | |
| 25-7 | 1900 | Note: Steady flow of approx. 2.5 cm$^3$/sec maintained from 1900 hrs to 2115 hrs at 17 psi. Head loss unknown. | | | | | | | | | | | | | | | |
| 25-7 | 2115 | - | - | - 25.0 | | +30.3 | -23.8 | 54.1 | 137.5 | 1000 | | 8 | 42 | 1.92 | $1.39 \times 10^{-2}$ | $3.70 \times 10^{-4}$ | $3.28 \times 10^{-4}$ |

## PERMEABILITY DATA SHEET

Sample No. 3 - Sheet #2

Initial Dry Density 127.0 #/ft$^3$

Material: Crawford Pit

L/A = 2.65x10$^{-2}$ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp.°C In | Temp.°C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. cm$^3$ | PH | Elaps. Time Min Sec | Q cm$^3$/s | $Q/H_L$ cm$^2$/sec. | K' cm/sec | K cm/sec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26-7 | 1525 | - | - | - | 24.8 | +30.5 | -23.1 | 53.6 | 136.2 | 1000 | | 6-35 | 2.54 | $1.86\times10^{-2}$ | $4.92\times10^{-4}$ | $4.38\times10^{-4}$ |
| " | 1540 | - | - | - | 25.0 | +30.2 | -23.3 | 53.5 | 136.0 | 1000 | | 6-57 | 2.40 | $1.76\times10^{-2}$ | $4.66\times10^{-4}$ | $4.14\times10^{-4}$ |
| " | 1710 | - | - | - | 25.4 | +30.1 | -23.6 | 53.7 | 136.5 | 1000 | | 7-56 | 2.10 | $1.54\times10^{-2}$ | $4.08\times10^{-4}$ | $3.60\times10^{-4}$ |
| " | 1915 | - | - | - | 25.2 | +30.1 | -23.7 | 53.8 | 137.0 | 1000 | | 8-42 | 1.92 | $1.40\times10^{-2}$ | $3.71\times10^{-4}$ | $3.27\times10^{-4}$ |
| " | 2230 | - | - | - | 25.1 | +30.1 | -24.0 | 54.1 | 137.5 | 1000 | | 10-13 | 1.63 | $1.19\times10^{-2}$ | $3.16\times10^{-4}$ | $2.80\times10^{-4}$ |
| 27-7 | 0535 | - | - | - | 24.0 | +30.3 | -24.3 | 54.6 | 139.0 | 1000 | | 20-56 | 0.795 | $5.72\times10^{-3}$ | $1.52\times10^{-4}$ | $1.38\times10^{-4}$ |
| " | 0800 | - | - | - | 24.0 | +30.3 | -24.9 | 55.2 | 140.1 | 1000 | | 24-31 | 0.695 | $4.85\times10^{-3}$ | $1.28\times10^{-4}$ | $1.16\times10^{-4}$ |
| " | 1140 | - | - | - | 24.0 | +30.3 | -24.9 | 55.2 | 140.1 | 1000 | | 27-10 | 0.614 | $4.38\times10^{-3}$ | $1.16\times10^{-4}$ | $1.05\times10^{-4}$ |
| " | 1600 | - | - | - | 24.0 | +30.3 | -25.0 | 55.3 | 140.5 | 1000 | 8.2 | 30-32 | 0.545 | $3.88\times10^{-3}$ | $1.03\times10^{-4}$ | $9.35\times10^{-5}$ |
| " | 2100 | - | - | - | 24.0 | +30.2 | -25.1 | 55.3 | 140.5 | 250 | | 9-22 | 0.445 | $3.17\times10^{-3}$ | $8.40\times10^{-5}$ | $7.64\times10^{-5}$ |
| 28-7 | 1230 | - | - | - | 23.5 | +30.2 | -25.3 | 55.5 | 141.0 | 250 | 8.2 | 16-08 | 0.258 | $1.83\times10^{-3}$ | $4.75\times10^{-5}$ | $4.36\times10^{-5}$ |
| " | 1305 | Outlet valve closed - Sample at rest | | | | | | | | | | | | | | |

## PERMEABILITY DATA SHEET

Sample No. 3 - Sheet #3 — Initial Dry Density 127.0 #/ft$^3$

Material: Crawford Pit — $L/A = 2.65 \times 10^{-2}$ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp.°C In | Temp.°C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. cm$^3$ | PH | Elaps. Time Min. Sec | Q cm$^3$/s | Q/HL cm$^2$/sec. | K' cm/sec | K cm/sec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 29-7 | 2035 | 6869 | | | | +30.3 | +30.3 | - nil - | | (Initial Dial Rd.) | | | | | | |
| " | 2041 | Flow started - | | | | | | | | | | | | | | |
| | 41.5 | 6850 | | | | | | | | | | | | | | |
| | 42.25 | 45 | | | | | | | | | | | | | | |
| | 42.75 | 40 | | | | | | | | | | | | | | |
| | 43 | | | | | +30.3 | -24.9 | (Started Collecting effluent) | | | | | | | | |
| | 44 | 36 | | | | | | | | | | | | | | |
| | 45 | 33 | | | | | | | | 100 | | 2-22 | | | | |
| | 47 | 31 | | | | | | | | 200 | | 4-45 | | | | |
| | 50 | 29 | | | | | | | | 300 | | 7-05 | | | | |
| | 52 | 26 | | 24.0 | | | | | | 400 | | 9-40 | | | | |
| | 54 | 25 | | | | | | | | 500 | | 12-06 | | | | |
| | 57 | 23 | | | | | | | | 600 | | 14-38 | | | | |
| | 2100 | 6822 | | | | | | | | 700 | | 17-05 | | | | |
| | 02 | 22 | | | | | | | | 800 | | 19-40 | | | | |
| | 06 | 21 | | | | | | | | 900 | | 22-18 | | | | |
| | 09 | 19 | | | | +30.3 | -24.9 | 52.5 | 140.2 | 1000 | 9.0 | 24-53 | 0.670 | $4.77 \times 10^{-3}$ | $1.27 \times 10^{-4}$ | $1.15 \times 10^{-4}$ |
| | 22 | 17 | | | | | | | | | | | | | | |
| | 23 | Started collecting effluent. | | | | | | | | | | | | | | |
| | 29 | 16 | | | | +30.3 | -25.0 | 55.3 | 140.5 | 250 | 9.0 | 6-46 | 0.615 | $4.38 \times 10^{-3}$ | $1.16 \times 10^{-4}$ | $1.06 \times 10^{-4}$ |

## PERMEABILITY DATA SHEET

Sample No. 3 Sheet #4 — Initial Dry Density 127.0 #/ft$^3$

Material: Crawford Pit — $L/A$ = 2.65 x $10^{-2}$ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp.°C In | Temp.°C Out | Total Head In | Total Head out | $H_1$ in. | $H_1$ cm. | Effluent Vol. cm$^3$ | Effluent PH | Elaps. Time Min Sec | Q cm$^3$/s | Q/HL cm$^2$/sec. | K' cm/sec | K cm/sec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 29-7 | 2132 | | | | 24.0 | +30.3 | -25.0 | 55.3 | 140.5 | (Started Collecting Effluent) | | | | | | |
| | 39 | | | | | +30.3 | -25.0 | 55.3 | 140.5 | 250 | 9.0 | 6-50 | 0.610 | $4.34\times10^{-3}$ | $1.15\times10^{-4}$ | $1.04\times10^{-4}$ |
| | 40 | 6811 | | | | | | | | | | | | | | |
| | 46 | 10 | | | | +30.3 | -25.0 | 55.3 | 140.5 | (Started Collecting Effluent) | | | | | | |
| | 53 | 09 | | | | +30.3 | -25.0 | 55.3 | 140.5 | 250 | 8.9 | 7-00 | 0.595 | $4.23\times10^{-3}$ | $1.12\times10^{-4}$ | $1.02\times10^{-4}$ |
| | 2215 | 08 | | | 24.0 | | | | | | | | | | | |
| | 2239 | 07 | | | | +30.3 | -25.1 | 55.4 | 141.0 | | | | | | | |
| | 40 | | | | | (Started Collecting Effluent) | | | | | | | | | | |
| | 48 | | | | | +30.3 | -25.1 | 55.4 | 141.0 | 250 | 9.1 | 7-44 | 0.538 | $3.82\times10^{-3}$ | $1.01\times10^{-4}$ | $9.18\times10^{-5}$ |
| | 2258 | 6805 | | | | | | | | | | | | | | |
| 30-7 | 0950 | 6790 | | | 23.0 | +30.2 | -25.2 | 55.4 | 141.0 | | | | | | | |
| | 1008 | | | | | (Started Collecting Effluent) | | | | | | | | | | |
| | 21 | | | | | +30.2 | -25.2 | 55.4 | 141.0 | 250 | 9.2 | 12-33 | 0.332 | $2.36\times10^{-3}$ | $6.24\times10^{-5}$ | $5.81\times10^{-5}$ |
| | 1105 | 6789 | | | | | | | | | | | | | | |
| | 1257 | 6787 | | | | | | | | | | | | | | |
| | 1633 | 6784 | | | | | | | | | | | | | | |
| | 1642 | | | | | +30.2 | -25.2 | 55.4 | 141.0 | 250 | - | 13-27 | 0.310 | $2.20\times10^{-3}$ | $5.82\times10^{-5}$ | $5.33\times10^{-5}$ |
| | 1925 | 6782 | | | 23.6 | +30.0 | -25.3 | 55.3 | 140.5 | 150 | - | 8-04 | 0.310 | $2.20\times10^{-3}$ | $5.82\times10^{-5}$ | $5.33\times10^{-5}$ |
| | 1936 | | | | | +30.0 | -25.3 | 55.3 | 140.5 | 250 | | 13-57 | 0.299 | $2.12\times10^{-3}$ | $5.63\times10^{-5}$ | $5.16\times10^{-5}$ |
| 31-7 | 1030 | 6777 | | | 23.2 | +30.3 | -25.3 | 55.6 | 141.2 | 250 | | 15-52 | 0.263 | $1.86\times10^{-3}$ | $4.92\times10^{-5}$ | $4.55\times10^{-5}$ |

## PERMEABILITY DATA SHEET

Sample No. 3 Sheet #5

Material: Crawford Pit

Initial Dry Density 127.0 #/ft$^3$

$L/A = 2.65 \times 10^{-2}$ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp. °C In | Temp. °C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. cm$^3$ | Effluent PH | Elaps. Time Min | Elaps. Time Sec | Q cm$^3$/s | Q/HL cm$^2$/sec. | K' cm/sec | K cm/sec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31-7 | 1057 | 6777 | | | | +30.3 | -25.3 | 55.6 | 141.2 | (Outlet valve closed) | | | | | | | |
| | 1108 | 6790 | | | | +30.3 | +26.0 | | | (No flow) | | | | | | | |
| | 1127 | 6800 | | | | +30.3 | +30.3 | | | ( " " ) | | | | | | | |
| | 1230 | 6810 | | | | " | " | | | " " | | | | | | | |
| | 1335 | 6811 | | | | | | | | | | | | | | | |
| | 1338 | 6811 | | | | (Flow Started) | | | | | | | | | | | |
| | 1340 | 6793 | | | | +30.3 | -25.3 | 55.6 | 141.2 | Collection Started | | | | | | | |
| | 1351 | 6783 | | | | | | | | | | | | | | | |
| | 1355 | 6781 | | | 23.2 | +30.2 | -25.3 | 55.6 | 141.2 | 250 | | 15 | 00 | 0.278 | $1.97 \times 10^{-3}$ | $5.23 \times 10^{-5}$ | $4.84 \times 10^{-5}$ |
| | 1358 | | | | | (Permeameter shut off) | | | | | | | | | | | |

## PERMEABILITY DATA SHEET

Sample No. 3 Sheet #6 — Initial Dry Density 127.0 #/ft$^3$

Material: Crawford Pit — $L/A = 2.65 \times 10^{-2}$ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp.°C In | Temp.°C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. PH cm$^3$ | Elaps. Time Min Sec | Q cm$^3$/s | Q/HL cm$^2$/sec. | K' cm/sec | K cm/sec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31-7 | | | | Permeameter Feed changed from constant head tank to Pressure Header tank. | | | | | | | | | | | |
| 31-7 | 1527 | 6840 | | (Initial Dial Rd. - No flow) | | | | | | | | | | | |
| | 30 | 6768 | | 23.6 | (8.05" Hg) | | | 278 | 250 | | 3-27 | 1.21 | $4.34\times10^{-3}$ | $1.15\times10^{-4}$ | $1.05\times10^{-4}$ |
| | 42 | 6678 | | | (12.50" Hg) | | | 432 | 250 | | 2-34 | 1.62 | $3.75\times10^{-3}$ | $9.92\times10^{-5}$ | $9.08\times10^{-5}$ |
| | 51 | 6605 | | | (16.85" Hg) | | | 582 | 250 | | 1-47 | 2.32 | $3.97\times10^{-3}$ | $1.05\times10^{-4}$ | $9.62\times10^{-5}$ |
| | 55 | 6555 | | | (19.95" Hg) | | | 689 | 250 | | 1-36 | 2.60 | $3.78\times10^{-3}$ | $1.01\times10^{-4}$ | $9.25\times10^{-5}$ |
| | 1658 | 6535 | | | (19.83" Hg) | | | 685 | 250 | | 1-42 | 2.44 | $3.56\times10^{-3}$ | $9.44\times10^{-5}$ | $8.65\times10^{-5}$ |
| | 1606 | 6527 | | 23.6 | (19.81" Hg) | | | 684 | 250 | | 1-44 | 2.40 | $3.51\times10^{-6}$ | $9.30\times10^{-5}$ | $8.52\times10^{-5}$ |
| | 1610 | | (Permeameter Shut Down) | | | | | | | | | | | | |
| 10-8 | 1120 | 6842 | | Dial Rd. after 10 days at rest | | | | | | | | | | | |
| | 1125 | 6830 | | 22.6 | ( 3.52" Hg) | | | 121.5 | 250 | | 3-54 | 1.07 | $8.80\times10^{-3}$ | $2.33\times10^{-4}$ | $2.19\times10^{-4}$ |
| | 1135 | 6725 | | | (10.50" Hg) | | | 362 | 250 | | 2-10 | 1.92 | $5.45\times10^{-3}$ | $1.44\times10^{-4}$ | $1.35\times10^{-4}$ |
| | 1140 | 6620 | | | (15.55" Hg) | | | 537 | 250 | | 1-32 | 2.72 | $5.06\times10^{-3}$ | $1.34\times10^{-4}$ | $1.26\times10^{-4}$ |
| | 1145 | 6559 | | | (19.70" Hg) | | | 681 | 250 | | 1-17 | 3.24 | $4.76\times10^{-3}$ | $1.26\times10^{-4}$ | $1.18\times10^{-4}$ |
| | 1200 | 6570 | | 22.6 | (19.40" Hg) | | | 670 | 250 | | 1-22 | 3.05 | $4.55\times10^{-3}$ | $1.21\times10^{-4}$ | $1.14\times10^{-4}$ |

## PERMEABILITY DATA SHEET

Sample No. 4

Initial Dry Density 130.3 #/ft$^3$

Material: Crawford Pit (-3") + 1% Lime + 2% Fly Ash

$L/_A$ = 3.11 x $10^{-2}$ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp. °C In | Temp. °C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. cm$^3$ | Effluent PH | Elaps. Time Min Sec | Q cm$^3$/s | Q/HL cm$^2$/sec. | K' cm/sec | K cm/sec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19-8 | 2153 | 7305 | | 24.0 | | 15.7 | 15.7 | No flow. | | | | | | | | |
| | 2218 | 7289 | 7288 | 24.0 | 22.2 | +15.7 | -29.4 | 45.1 | 114.5 | 250 | 11.20 | 22-07 | 0.188 | $1.65 \times 10^{-3}$ | $5.12 \times 10^{-5}$ | $4.95 \times 10^{-5}$ |
| | 2355 | 7295 | 7296 | 24.0 | 22.2 | +14.2 | -29.3 | 43.5 | 110.5 | 250 | 11.16 | 17-45 | 0.234 | $2.12 \times 10^{-3}$ | $6.60 \times 10^{-5}$ | $6.25 \times 10^{-5}$ |
| 20-8 | 0952 | 7335 | 7337 | 23.5 | 21.0 | + 8.1 | -29.4 | 37.5 | 95.3 | 500 | 11.00 | 36-53 | 0.226 | $2.47 \times 10^{-3}$ | $7.36 \times 10^{-5}$ | $7.18 \times 10^{-5}$ |
| | 1443 | 7345 | | 23.2 | 21.5 | + 6.0 | -29.4 | | | | | | | | | |
| | 1534 | 7346 | 7346 | 23.2 | 21.6 | + 5.6 | -29.4 | 35.0 | 89.0 | 150 | | 13-29 | 0.186 | $2.10 \times 10^{-3}$ | $6.50 \times 10^{-5}$ | $6.25 \times 10^{-5}$ |
| | 2020 | 7351 | 7351 | 23.0 | 21.5 | + 4.0 | -29.4 | 33.4 | 86.0 | 250 | 10.90 | 26-12 | 0.159 | $1.85 \times 10^{-3}$ | $5.75 \times 10^{-5}$ | $5.54 \times 10^{-5}$ |
| | | | | | | End of Run | | | | | | | | | | |

PERMEABILITY DATA SHEET

Sample No. 5

Initial Dry Density 131.6 #/ft$^3$

Material: Crawford Pit - (Natural)

$L/_A$ = 3.02 x $10^{-2}$ $cm^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp. °C In | Temp. °C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. $cm^3$ | Effluent PH | Elaps. Time Min Sec | Q $cm^3/s$ | Q/HL $cm^2$/sec. | K' cm/sec | K cm/sec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20-8 | 2019 | 9725 | 9719 | 23.1 | 21.1 | (18.73" Hg) | | 255 | 647 | 100 | | 12-10 | 0.137 | $2.12 \times 10^{-4}$ | $6.40 \times 10^{-6}$ | $6.23 \times 10^{-6}$ |
| | 2034 | 9717 | 9717 | 23.0 | 21.5 | (18.69" Hg) | | 254 | 646 | 250 | 8.3 | 35-31 | 0.117 | $1.81 \times 10^{-4}$ | $5.45 \times 10^{-6}$ | $5.25 \times 10^{-6}$ |
| | 2115 | 9717 | 9718 | 23.0 | 21.5 | (18.66" Hg) | | 254 | 645 | 190 | 8.7 | 33-09 | .0955 | $1.48 \times 10^{-4}$ | $4.46 \times 10^{-6}$ | $4.30 \times 10^{-6}$ |
| | 2157 | 9719 | 9720 | 23.0 | 21.6 | (18.64" Hg) | | 254 | 644 | 100 | | 20-04 | .0830 | $1.29 \times 10^{-4}$ | $3.90 \times 10^{-6}$ | $3.76 \times 10^{-6}$ |
| | | Steady Flow Maintained | | | | | | | | | | | | | | |
| 21-8 | 1000 | 9895 | 9895 | 21.6 | 20.6 | (18.60" Hg) | | 253 | 643 | 60 | 8.6 | 40-43 | 0.245 | $3.81 \times 10^{-5}$ | $1.15 \times 10^{-6}$ | $1.13 \times 10^{-6}$ |

## PERMEABILITY DATA SHEET

Sample No. 6 Sheet #1 — Initial Dry Density 117.5 #/ft$^3$

Material: Crawford Pit (-3") — $L/_A = 3.35 \times 10^{-2}$ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp. °C In | Temp. °C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. cm$^3$ | Effluent PH | Elaps. Time Min Sec | Q cm$^3$/s | Q/HL cm$^2$/sec. | K' cm/sec. | K cm/sec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21-8 | 1645 | 0050 | | | | 23.6 | 23.6 | No Flow | | | | | | | | |
| | 1951 | 0195 | | | | 23.6 | 23.6 | " | " | | | | | | | |
| | 1952 | Flow Started | | | | | | | | | | | | | | |
| | 1959 | 0178 | 0177 | 24.6 | 24.1 | +17.9 | + 4.5 | 13.4 | 34.0 | 1000 | | 1-34 | 10.6 | 0.312 | $1.05\times10^{-2}$ | $9.55\times10^{-3}$ |
| | 2001 | 0176 | 0175 | 24.6 | 24.1 | +17.0 | + 3.5 | 13.5 | 34.2 | 1000 | | 1-31 | 11.0 | 0.322 | $1.07\times10^{-2}$ | $9.72\times10^{-3}$ |
| | 2006 | 0175 | 0175 | 24.7 | 24.1 | +15.4 | + 2.1 | 13.3 | 33.8 | 1000 | | 1-29 | 11.2 | 0.332 | $1.11\times10^{-2}$ | $1.01\times10^{-2}$ |
| | 2009 | 0175 | 0176 | 24.8 | 24.1 | +14.3 | + 1.7 | 12.6 | 32.0 | 1000 | | 1-28 | 11.3 | 0.353 | $1.17\times10^{-2}$ | $1.06\times10^{-2}$ |
| | 2017 | 0178 | 0178 | 25.0 | 24.0 | +11.6 | - 2.0 | 13.6 | Error in monometer reading | | | | | | | |
| | 2027 | 0178 | 0178 | 25.0 | 24.0 | + 8.1 | - 3.1 | 11.2 | 28.5 | 1000 | | 1-32 | 10.8 | 0.380 | $1.27\times10^{-2}$ | $1.15\times10^{-2}$ |
| | 2046 | 0180 | 0180 | 25.0 | 24.0 | + 2.3 | - 7.3 | 9.6 | | | | N.R. | | | | |
| | 2048 | 0180 | 0180 | 25.0 | 24.0 | + 1.7 | - 7.7 | 9.4 | 23.8 | 1000 | | 1-45 | 9.52 | 0.400 | $1.34\times10^{-2}$ | $1.22\times10^{-2}$ |
| | 2056 | 0181 | 0181 | 25.0 | 24.0 | - 0.6 | - 9.3 | 8.7 | 22.1 | 1000 | | 1-51 | 9.00 | 0.406 | $1.36\times10^{-2}$ | $1.24\times10^{-2}$ |
| | 2100 | Outlet Valve Closed. | | | | | | | | | | | | | | |
| 22-8 | 1032 | 0317 | | No Flow | | | | | | | | | | | | |
| | 1038 | 0311 | 0310 | 22.0 | 21.0 | - 2.2 | -10.6 | 8.4 | 21.3 | 1000 | | 2-02 | 8.00 | 0.378 | $1.26\times10^{-2}$ | $1.23\times10^{-2}$ |
| | 1048 | 0309 | 0309 | 22.0 | 21.0 | - 4.7 | -12.4 | 7.7 | 19.6 | 1000 | | 2-14 | 7.46 | 0.380 | $1.27\times10^{-2}$ | $1.24\times10^{-2}$ |
| | 1109 | 0312 | 0312 | 22.0 | 21.0 | direct Ms. | | 7.5 | 19.0 | 1000 | | 2-17 | 7.30 | 0.384 | $1.29\times10^{-2}$ | $1.26\times10^{-2}$ |

* Sample prepared by dynamic compaction.

## PERMEABILITY DATA SHEET

Sample No. 6 Sheet #2 — Initial Dry Density 117.5 #/ft$^3$

Material: Crawford Pit (-3") — $L/_A$ = 3.35 x $10^{-2}$ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp. °C In | Temp. °C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. cm$^3$ | Effluent PH | Elaps. Time Min Sec | Q cm$^3$/s | Q/HL cm$^2$/sec. | K' cm/sec. | K cm/sec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22-8 | 1320 | 0333 | | | | No Flow | | | | | | | | | | |
| | 1325 | 0327 | 0326 | 27.0 | 21.5 | +17.6 | + 4.0 | 13.6 | 34.5 | 1000 | | 1-18 | 12.7 | 0.368 | $1.23\times10^{-2}$ | $1.19\times10^{-2}$ |
| | 1328 | 0325 | 0324 | 27.5 | 21.5 | +16.4 | + 3.2 | 13.2 | 33.5 | 1000 | | 1-19 | 12.6 | 0.376 | $1.26\times10^{-2}$ | $1.21\times10^{-2}$ |
| | 1332 | 0322 | 0322 | 28.0 | 22.0 | +15.0 | + 2.2 | 12.8 | 32.5 | 1000 | | 1-21 | 12.4 | 0.381 | $1.28\times10^{-2}$ | $1.22\times10^{-2}$ |
| Statically Recompacted Density = 120.9 #/ft. $L/_A$ = 3.27 x $10^{-2}$ | | | | | | | | | | | | | | | | |
| 26-8 | 1130 | 3462 | 3461 | 23.4 | 21.0 | +14.6 | -20.6 | 35.2 | 89.4 | 250 | | 19-55 | 0.209 | $2.32\times10^{-3}$ | $7.65\times10^{-5}$ | $7.46\times10^{-5}$ |
| | 1155 | 3461 | 3461 | 23.4 | 21.0 | +14.3 | -20.7 | 35.0 | 89.0 | 500 | | 41-06 | 0.203 | $2.28\times10^{-3}$ | $7.45\times10^{-5}$ | $7.27\times10^{-5}$ |
| | 1350 | 3400 | 3392 | 24.0 | 21.3 | (16.11" Hg) | | 219 | 556 | 1000 | | 9-58 | 1.67 | $3.02\times10^{-3}$ | $9.88\times10^{-5}$ | $9.58\times10^{-5}$ |
| | 1410 | 3392 | 3388 | 24.0 | 21.3 | (16.00" Hg) | | 218 | 553 | 250 | | 2-32 | 1.59 | $2.88\times10^{-3}$ | $9.40\times10^{-5}$ | $9.11\times10^{-5}$ |
| Statically Recompacted Density = 123.2 #/ft$^3$ $L/_A$ = 3.20 x $10^{-2}$ | | | | | | | | | | | | | | | | |
| 26-8 | 1639 | 5883 | 74 | 24.0 | 21.3 | (15.70" Hg) | | 214 | 542 | 250 | | 14-09 | 0.284 | $5.41\times10^{-4}$ | $1.73\times10^{-5}$ | $1.68\times10^{-5}$ |
| | 1703 | 5868 | 5862 | 24.0 | 21.3 | (17.41" Hg) | | 237 | 602 | 250 | | 12-35 | 0.331 | $5.51\times10^{-4}$ | $1.76\times10^{-5}$ | $1.71\times10^{-5}$ |

PERMEABILITY DATA SHEET

Sample No. 6 Sheet #3

Initial Dry Density _____ #/ft$^3$

Material: Crawford Pit (-3")

$L/_A$ = _____ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp. °C In | Temp. °C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. cm$^3$ | Effluent PH | Elaps. Time Min Sec | Q cm$^3$/s | Q/HL cm$^2$/sec. | K' cm/sec. | K cm/sec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Statically Recompacted Density = 126.2 #/ft$^3$ | | | | | | | | $L/_A$ = 3.13 x $10^{-2}$ | | | | | | |
| 26-8 | 2122 | 1041 | | 23.6 | 21.0 | (16.75" Hg) | 228 | | 578 | 110 | | 24-22 | .0752 | $1.30 \times 10^{-4}$ | $4.06 \times 10^{-6}$ | $3.97 \times 10^{-6}$ |
| | 2230 | 1032 | | | | (16.75" Hg) | 228 | | 578 | 190 | | 45-04 | .0702 | $1.22 \times 10^{-4}$ | $3.81 \times 10^{-6}$ | $3.72 \times 10^{-6}$ |
| | | Statically Recompacted Density 129.5 #/ft$^3$ | | | | | | | | $L/_A$ = 3.05 x $10^{-2}$ | | | | | | |
| 27-8 | 1350 | 8934 | 8948 | 23.4 | 21.0 | (18.92" Hg) | 258 | | 654 | 50 | | 46-22 | .0180 | $2.75 \times 10^{-5}$ | $8.40 \times 10^{-7}$ | $8.20 \times 10^{-7}$ |

PERMEABILITY DATA SHEET

Sample No. 7 Sheet #1 — Initial Dry Density 118.1 #/ft$^3$

Material: Crawford Pit (-3") — $L/A = 3.34 \times 10^{-2}$ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp. °C In | Temp. °C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. cm$^3$ | Effluent PH | Elaps. Time Min Sec | Q cm$^3$/s | Q/HL cm$^2$/sec. | K' cm/sec. | K cm/sec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-9 | 1615 | 7448 | | (Initial Dial Rd.) | | | | No Flow | | | | | | | | |
| | 1618 | 7426 | 7425 | 22.5 | 23.4 | + 4.3 | -15.2 | 19.5 | 49.5 | 1000 | | 2-25 | 6.90 | 0.139 | $4.65 \times 10^{-3}$ | $4.28 \times 10^{-3}$ |
| | 1623 | 7425 | 7426 | 22.5 | 23.4 | + 3.7 | -15.0 | 18.7 | 47.5 | 1000 | | 2-24 | 6.95 | 0.146 | $4.88 \times 10^{-3}$ | $4.50 \times 10^{-3}$ |
| | 1627 | 7429 | 7431 | 22.5 | 24.1 | + 2.3 | -14.7 | 17.0 | 43.2 | 1000 | | 2-22 | 7.05 | 0.163 | $5.45 \times 10^{-3}$ | $4.95 \times 10^{-3}$ |
| | 1630 | | Out let valve closed | | | | | | | | | | | | | |
| 1-9 | 1700 | 7478 | 7478 | 27.0 | 24.0 | +19.0 | - 4.0 | 23.0 | 58.4 | 1000 | | 1-34 | 10.6 | 0.182 | $6.07 \times 10^{-3}$ | $5.52 \times 10^{-3}$ |
| | 1705 | 7478 | 7478 | 27.0 | 24.0 | +17.3 | - 3.5 | 20.8 | 52.8 | 1000 | | 1-33 | 10.7 | 0.202 | $6.75 \times 10^{-3}$ | $6.14 \times 10^{-3}$ |
| | 1710 | 7478 | 7478 | 27.0 | 24.0 | +16.5 | - 3.3 | 19.8 | 50.2 | 1000 | | 1-33 | 10.7 | 0.212 | $7.08 \times 10^{-3}$ | $6.44 \times 10^{-3}$ |
| | 1712 | | Out let valve closed | | | | | | | | | | | | | |
| 1-9 | 1920 | 7472 | 7472 | 26.2 | 24.2 | +11.1 | - 4.4 | 16.5 | 41.9 | 1000 | | 1-36 | 10.4 | 0.249 | $8.30 \times 10^{-3}$ | $7.50 \times 10^{-3}$ |
| | 1925 | 7472 | 7472 | 26.2 | 24.2 | + 9.3 | - 4.7 | 14.0 | 35.5 | 1000 | | 1-37 | 10.3 | 0.290 | $9.7 \times 10^{-3}$ | $8.76 \times 10^{-3}$ |
| | 1937 | 7472 | 7472 | 26.2 | 24.2 | + 8.4 | - 5.0 | 13.4 | 34.0 | 1000 | | 1-38 | 10.2 | 0.300 | $1.01 \times 10^{-2}$ | $9.12 \times 10^{-3}$ |
| | 1942 | 7472 | 7472 | 26.2 | 24.2 | + 6.2 | - 6.0 | 12.2 | 32.0 | 1000 | | 1-41 | 9.90 | 0.310 | $1.04 \times 10^{-2}$ | $9.39 \times 10^{-3}$ |

## PERMEABILITY DATA SHEET

Sample No. 7 Sheet #2 — Initial Dry Density _____ #/ft$^3$

Material: Crawford Pit (-3") — $L/_A$ = _____ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp. °C In | Temp. °C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. cm$^3$ | Effluent PH | Elaps. Time Min Sec | Q cm$^3$/s | Q/HL cm$^2$/sec. | K' cm/sec. | K cm/sec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (Statically Recompacted Density = 123.5 #/ft | | | | $L/_A$ = 3.18 x $10^{-2}$) | | | | | | | | | | |
| 3-8 | 1135 | 8288 | | (Initial Dial Rd.) | | (No Flow) | | | | | | | | | | |
| | 1142 | 8282 | 8220 | 22.5 | 22.2 | (18.10" Hg) | 246 | | 625 | 250 | | 3-48 | 1.10 | $1.76\times10^{-3}$ | $5.60\times10^{-5}$ | $5.32\times10^{-5}$ |
| | 1157 | 8215 | 8214 | 22.5 | 22.2 | (18.25" Hg) | 248 | | 631 | 250 | | 4-15 | 0.98 | $1.55\times10^{-3}$ | $4.95\times10^{-5}$ | $4.70\times10^{-5}$ |
| | 1338 | 8198 | 8198 | 23.0 | 22.3 | (18.02" Hg) | 245 | | 623 | 250 | | 5-47 | 0.72 | $1.16\times10^{-3}$ | $3.68\times10^{-5}$ | $3.49\times10^{-5}$ |
| | | (Statically Recompacted Density = 129.8 #/ft$^3$ | | | | $L/_A$ = 3.04 x $10^{-2}$) | | | | | | | | | | |
| 3-8 | 1508 | 7305 | 7302 | 23.0 | 22.5 | (18.25" Hg) | 248 | | 631 | 50 | | 6-03 | 0.138 | $2.18\times10^{-4}$ | $6.65\times10^{-6}$ | $6.25\times10^{-6}$ |
| | 1520 | 7300 | 7300 | 23.0 | 22.5 | (17.80" Hg) | 242 | | 614 | 311 | | 42-35 | 0.122 | $1.98\times10^{-4}$ | $6.05\times10^{-6}$ | $5.69\times10^{-6}$ |

## PERMEABILITY DATA SHEET

Sample No. 8

Initial Dry Density 123.5 #/ft$^3$

Material: Crawford Pit (-3")

$L/_A$ = 3.21 x $10^{-1}$ $cm^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp. °C In | Temp. °C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. $cm^3$ | Effluent PH | Elaps. Time Min Sec | Q $cm^3/s$ | Q/HL $cm^2/sec.$ | K' cm/sec. | K cm/sec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 29-8 | 2058 | 6578 | 6566 | 21.5 | 21.5 | +18.4 | -29.4 | 47.8 | 105.2 | 250 | | 8-38 | 0.482 | $4.57x10^{-3}$ | $1.47x10^{-4}$ | $1.40x10^{-4}$ |
| | 2108 | 6564 | 6557 | 21.5 | 21.5 | +18.1 | -29.4 | 47.5 | 104.5 | 250 | | 8-42 | 0.478 | $4.57x10^{-3}$ | $1.47x10^{-4}$ | $1.40x10^{-4}$ |
| | | Statically Recompacted Density = 131.0 #/ft$^3$ | | | | | $L/_A$ = 3.03 x $10^{-2}$ | | | | | | | | | |
| 30-8 | 1617 | 5318 | 5298 | 22.0 | NB | (20.10" Hg) | 263 | 695 | | 10 | | 39-00 | .00427 | $6.15x10^{-6}$ | $1.90x10^{-7}$ | $1.81x10^{-7}$ |

## PERMEABILITY DATA SHEET

Sample No. 9

Initial Dry Density 118.5 #/ft$^3$

Material: Crawford Pit - Natural

$L/A = 3.27 \times 10^{-2}$ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp. °C In | Temp. °C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. cm$^3$ | Effluent PH | Elaps. Time Min Sec | Q cm$^3$/s | Q/HL cm$^2$/sec. | K' cm/sec. | K cm/sec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31-8 | 1453 | 4823 | 4820 | 21.5 | 22.0 | +5.0 | -6.7 | 11.7 | 29.7 | 1000 | | 1-32 | 10.9 | 0.367 | $1.20\times10^{-2}$ | $1.14\times10^{-2}$ |
| " | 1500 | 4810 | 4809 | 21.5 | 22.2 | +4.5 | -6.7 | 11.2 | 28.4 | 1000 | | 1-31 | 10.9 | 0.384 | $1.25\times10^{-2}$ | $1.18\times10^{-2}$ |
| " | 1505 | 4809 | 4809 | 21.5 | 22.0 | +3.8 | -6.8 | 10.6 | 26.9 | 1000 | | 1-32 | 10.9 | 0.405 | $1.32\times10^{-2}$ | $1.26\times10^{-2}$ |
| | | Density = 121.2 #/ft$^3$ | | | | | | $L/A = 3.19 \times 10^{-2}$ | | | | | | | | |
| 31-8 | 1906 | 4795 | 4795 | 23.0 | 21.8 | +16.6 | -24.4 | 41.0 | 104.1 | 1000 | | 10-33 | 1.58 | $1.52\times10^{-2}$ | $4.76\times10^{-4}$ | $4.55\times10^{-4}$ |
| " | 1924 | 4796 | 4797 | 23.0 | 21.7 | +15.7 | -24.2 | 39.9 | 101.5 | 1000 | | 10-02 | 1.61 | $1.64\times10^{-2}$ | $5.15\times10^{-4}$ | $4.94\times10^{-4}$ |
| " | 1949 | 4798 | 4798 | 23.0 | 21.8 | +14.6 | -24.2 | 38.8 | 98.5 | 1000 | | 10-25 | 1.60 | $1.63\times10^{-2}$ | $5.10\times10^{-4}$ | $4.89\times10^{-4}$ |
| | | Density = 128.5 #/ft$^3$ | | | | | | $L/A = 3.02 \times 10^{-2}$ | | | | | | | | |
| 31-8 | 2230 | 4768 | 4768 | 22.8 | 22.0 | (19.05" Hg) | | 259 | 658 | 50 | | 1-50 | 0.454 | $6.90\times10^{-4}$ | $2.08\times10^{-5}$ | $1.98\times10^{-5}$ |
| " | 2236 | 4768 | 4768 | 22.8 | 22.0 | (19.05" Hg) | | 259 | 658 | 50 | | 1-49 | 0.456 | $6.92\times10^{-4}$ | $2.09\times10^{-5}$ | $1.99\times10^{-5}$ |
| " | 2250 | 4770 | 4770 | 22.8 | 22.0 | (19.08" Hg) | | 259 | 659 | 50 | | 2-08 | 0.390 | $5.91\times10^{-4}$ | $1.79\times10^{-5}$ | $1.71\times10^{-5}$ |
| " | 2300 | 4771 | 4771 | 22.8 | 22.0 | (19.08" Hg) | | 259 | 659 | 50 | | 2-05 | 0.400 | $6.07\times10^{-4}$ | $1.88\times10^{-5}$ | $1.79\times10^{-5}$ |

PERMEABILITY DATA SHEET

Sample No. 11 Sheet #1

Initial Dry Density 120.5 #/ft$^3$

Material: Crawford Pit (-3") + 0.5% N.P.C.

$L/_A$ = 3.31 x $10^{-2}$ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp. °C In | Temp. °C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. cm$^3$ | Effluent PH | Elaps. Time Min Sec | Q cm$^3$/s | Q/HL cm$^2$/sec. | K' cm/sec. | K cm/sec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4-9 | 2219 | 3672 | 3672 | 23.0 | 24.5 | + 1.0 | -11.7 | 21.1 | 30.7 | 1000 | | 2-01 | 8.26 | $2.69\times10^{-1}$ | $8.90\times10^{-3}$ | $8.00\times10^{-3}$ |
| | 2222 | 3672 | 3672 | 23.0 | 24.5 | + 0.2 | -11.3 | 11.5 | 29.2 | 1000 | | 2-02 | 8.20 | $2.81\times10^{-1}$ | $9.30\times10^{-3}$ | $8.36\times10^{-3}$ |
| | 2228 | 3675 | 3677 | 23.0 | 25.0 | - 1.6 | -12.0 | 10.4 | 26.4 | 1000 | | 2-06 | 7.92 | $3.12\times10^{-1}$ | $1.03\times10^{-2}$ | $9.02\times10^{-3}$ |
| | 2234 | 3677 | | Out let valve closed. | | | | | | | | | | | | |
| 5-9 | 1047 | 3747 | 3747 | 22.0 | 22.5 | - 3.0 | -13.2 | 10.2 | 25.9 | 1000 | | 2-16 | 7.35 | $2.84\times10^{-1}$ | $9.40\times10^{-3}$ | $8.85\times10^{-3}$ |
| | 1051 | 3747 | 3747 | 22.2 | 22.5 | - 4.0 | -13.7 | 9.7 | 24.6 | 1000 | | 2-19 | 7.20 | $2.93\times10^{-1}$ | $9.60\times10^{-3}$ | $9.05\times10^{-3}$ |
| | 1103 | 3747 | 3747 | 22.4 | 22.8 | - 6.7 | -15.1 | 8.4 | 21.3 | 1000 | | 2-36 | 6.62 | $3.11\times10^{-1}$ | $1.03\times10^{-2}$ | $9.70\times10^{-3}$ |
| | 1108 | (Outlet valve closed) | | | | | | | | | | | | | | |
| 5-9 | 1343 | 3758 | 3758 | 26.0 | 22.0 | +12.7 | - 0.9 | 13.6 | 34.5 | 1000 | | 1-29 | 11.2 | $3.25\times10^{-1}$ | $1.07\times10^{-2}$ | $1.02\times10^{-2}$ |
| | 1346 | 3758 | 3758 | 26.0 | 22.0 | +11.6 | - 1.1 | 12.7 | 32.3 | 1000 | | 1-30 | 11.1 | $3.44\times10^{-1}$ | $1.14\times10^{-2}$ | $1.09\times10^{-2}$ |

PERMEABILITY DATA SHEET

Sample No. 11 Sheet #2

Material: Crawford Pit (-3") + 0.5% N.P.C.

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp. °C In | Temp. °C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. $cm^3$ | Effluent PH | Elaps. Time Min Sec | Q $cm^3/s$ | Q/HL $cm^2$/sec. | K' cm/sec. | K cm/sec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Statically Recompacted Density = 126.1 #/$ft^3$ | | | | | | | | $L/_A$ = 3.16 x $10^{-2}$ | | | | | | |
| 5-9 | 1504 | 7713 | 7715 | 24.1 | 21.5 | +10.3 | -28.7 | 39.0 | 99.1 | 250 | | 4-34 | 0.912 | $9.20\times10^{-3}$ | $2.91\times10^{-4}$ | $2.80\times10^{-4}$ |
| | 1513 | 7718 | 7719 | 24.1 | 21.5 | +10.1 | -28.8 | 38.9 | 98.8 | 250 | | 4-39 | 0.895 | $9.10\times10^{-3}$ | $2.88\times10^{-4}$ | $2.77\times10^{-4}$ |
| 5-9 | 1536 | 7739 | 7739 | 27.0 | 21.5 | +22.8 | -28.5 | 51.3 | 130.5 | 250 | | 3-36 | 1.16 | $8.87\times10^{-3}$ | $2.80\times10^{-4}$ | $2.70\times10^{-4}$ |
| | 1542 | 7739 | 7739 | 27.0 | 21.5 | +22.5 | -28.5 | 51.0 | 129.5 | 250 | | 3-39 | 1.14 | $8.81\times10^{-3}$ | $2.78\times10^{-4}$ | $2.68\times10^{-4}$ |
| | | Statically Recompacted Density = 130.1 #/ft | | | | | | | | $L/_A$ = 3.06 x $10^{-2}$ | | | | | | |
| 5-9 | 2049 | 8098 | 8100 | 24.0 | N.R. | +18.7 | -28.7 | 47.4 | 120.5 | 50 | | 9-19 | .0894 | $7.41\times10^{-4}$ | $2.27\times10^{-5}$ | $2.19\times10^{-5}$ |
| | 2103 | 8106 | 8112 | 24.0 | 21.5 | +18.6 | -28.8 | 47.4 | 120.5 | 50 | | 9-31 | .0877 | $7.28\times10^{-4}$ | $2.23\times10^{-5}$ | $2.15\times10^{-5}$ |
| | 2130 | Outlet valve closed | | | | | | | | | | | | | | |
| 6-9 | 1637 | 8200 | 8200 | 22.0 | N.R. | +18.5 | -28.8 | 47.3 | 120.0 | 50 | | 9-55 | .0840 | $7.00\times10^{-4}$ | $2.14\times10^{-5}$ | $2.06\times10^{-5}$ |
| | 1714 | 8248* | 8248 | 22.0 | 21.5 | (14.94" Hg) | | | 516 | 250 | | 12-59 | 0.321 | $6.22\times10^{-4}$ | $1.90\times10^{-5}$ | $1.83\times10^{-5}$ |

* Dial Rd. Disturbed prior to run.

## PERMEABILITY DATA SHEET

Sample No. 12 — Initial Dry Density 120.5 #/ft$^3$

Material: Crawford Pit (-3") + 0.5% lime + 1.0% Fly Ash — $L/A = 3.34 \times 10^{-2}$ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp. °C In | Temp. °C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. cm$^3$ | Effluent PH | Elaps. Time Min Sec | Q cm$^3$/s | Q/HL cm$^2$/sec. | K' cm/sec. | K cm/sec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7-9 | 1202 | 4383 | 4382 | 21.5 | 21.0 | +11.6 | - 9.3 | 20.9 | 53.1 | 1000 | | 1-54 | 8.77 | 0.165 | $5.52\times10^{-3}$ | $5.40\times10^{-3}$ |
| | 1204 | 4382 | 4382 | 21.5 | 21.0 | +10.7 | - 9.6 | 20.3 | 51.6 | 1000 | | 1-55 | 8.70 | 0.169 | $5.64\times10^{-3}$ | $5.50\times10^{-3}$ |
| | 1207 | 4382 | 4382 | 21.2 | 21.0 | + 9.8 | -10.1 | 19.9 | 50.6 | 1000 | | 1-57 | 8.55 | 0.169 | $5.64\times10^{-3}$ | $5.50\times10^{-3}$ |
| | | Statically Recompacted Density = 125.2 #/ft$^3$ | | | | | | | | $L/A = 3.22 \times 10^{-2}$ | | | | | | |
| 7-9 | 1507 | 0284 | 0279 | 21.7 | 21.0 | + 7.5 | -24.1 | 31.6 | 80.3 | 1000 | | 11-40 | 1.43 | $1.78\times10^{-2}$ | $5.73\times10^{-4}$ | $5.58\times10^{-4}$ |
| | 1525 | 0273 | 0273 | 21.6 | 21.1 | + 6.9 | -28.5 | 35.4 | 89.9 | 250 | | 2-36 | 1.60 | $1.78\times10^{-2}$ | $5.73\times10^{-4}$ | $5.58\times10^{-4}$ |
| | 1538 | 0272 | 0272 | 21.6 | 21.1 | + 6.4 | -28.6 | 35.0 | 89.0 | 250 | | 2-39 | 1.57 | $1.77\times10^{-2}$ | $5.70\times10^{-4}$ | $5.55\times10^{-4}$ |
| | | Statically Recompacted Density = 129.7 #/ft$^3$ | | | | | | | | $L/A = 3.11 \times 10^{-2}$ | | | | | | |
| 7-9 | 2005 | 0928 | 0930 | 23.2 | 21.2 | (15.78" Hg) | | 214 | 545 | 250 | | 4-23 | 0.950 | $1.74\times10^{-3}$ | $5.42\times10^{-5}$ | $5.26\times10^{-5}$ |
| | 2015 | 0930 | 0930 | 23.2 | 21.2 | (15.75" Hg) | | | 544 | 250 | | 4-37 | 0.902 | $1.66\times10^{-3}$ | $5.17\times10^{-5}$ | $5.02\times10^{-5}$ |
| | 2022 | 0930 | 0930 | 23.2 | 21.2 | (15.75" Hg) | | | 544 | 250 | | 4-41 | 0.890 | $1.64\times10^{-3}$ | $5.09\times10^{-5}$ | $4.94\times10^{-5}$ |
| | 2030 | 0930 | 0930 | 23.2 | 21.2 | (15.73" Hg) | | | 544 | 250 | | 4-45 | 0.878 | $1.62\times10^{-3}$ | $5.03\times10^{-5}$ | $4.88\times10^{-5}$ |
| | 2040 | 0990 | 0999 | 23.2 | 21.2 | ( 6.90" Hg) | | 93.8 | 238 | 130 | | 5-14 | 0.414 | $1.74\times10^{-3}$ | $5.42\times10^{-5}$ | $5.26\times10^{-5}$ |

## PERMEABILITY DATA SHEET

Sample No. 13 Sheet #1

Initial Dry Density 119.2 #/ft$^3$

Material: _____

$L/_A$ = 3.33 x $10^{-2}$ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp. °C In | Temp. °C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. cm$^3$ | Effluent PH | Elaps. Time Min Sec | Q cm$^3$/s | Q/HL cm$^2$/sec. | K' cm/sec. | K cm/sec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10-9 | 2210 | 4012 | 4012 | 22.0 | 24.1 | +11.5 | - 6.2 | 17.7 | 45.0 | 1000 | | 1-42 | 9.80 | $2.18\times10^{-1}$ | $7.20\times10^{-3}$ | $6.54\times10^{-3}$ |
| | 2214 | 4013 | 4013 | 22.0 | 24.1 | +10.2 | - 5.8 | 16.0 | 40.6 | 1000 | | 1-41 | 9.90 | $2.44\times10^{-1}$ | $8.10\times10^{-3}$ | $7.35\times10^{-3}$ |
| | 2226 | 4013 | 4013 | 22.0 | 23.9 | + 9.5 | - 5.7 | 15.2 | 38.6 | 1000 | | 1-40 | 10.00 | $2.59\times10^{-1}$ | $8.60\times10^{-3}$ | $7.82\times10^{-3}$ |
| | 2236 | Outlet valve closed | | | | | | | | | | | | | | |
| 11-9 | 1106 | 4208 | 4208 | 21.0 | 21.0 | + 8.2 | - 6.3 | 14.5 | 36.8 | 1000 | | 1-44 | 9.61 | $2.61\times10^{-1}$ | $8.70\times10^{-3}$ | $8.50\times10^{-3}$ |
| | 1109 | 4208 | 4208 | 21.0 | 21.0 | + 7.4 | - 6.4 | 13.8 | 35.1 | 1000 | | 1-44 | 9.61 | $2.74\times10^{-1}$ | $9.10\times10^{-3}$ | $8.89\times10^{-3}$ |
| | | Statically Recompacted Density = 122.1 #/ft$^3$ | | | | | | | | $L/_A$ = 3.24 x $10^{-2}$ | | | | | | |
| 11-9 | 1427 | 0816 | 0810 | 22.0 | 20.5 | +19.1 | -29.3 | 48.4 | 123.0 | 250 | | 8-13 | 0.507 | $4.12\times10^{-3}$ | $1.34\times10^{-4}$ | $1.33\times10^{-4}$ |
| | 1440 | 0809 | 0805 | 22.0 | 20.5 | +18.9 | -29.3 | 48.2 | 122.5 | 250 | | 8-20 | 0.500 | $4.08\times10^{-3}$ | $1.32\times10^{-4}$ | $1.31\times10^{-4}$ |
| | 1500 | 0804 | 0802 | 22.0 | 20.6 | +18.6 | -29.2 | 47.8 | 121.5 | 250 | | 8-23 | 0.497 | $4.09\times10^{-3}$ | $1.33\times10^{-4}$ | $1.31\times10^{-4}$ |

## PERMEABILITY DATA SHEET

Sample No. 13 Sheet #2 — Initial Dry Density _____ #/ft$^3$

Material: Crawford Pit (-3") — $L/_A$ = _____ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp. °C In | Temp. °C Out | Total Head In | Total Head Out | $H_1$ in. | $H_1$ cm. | Effluent Vol. cm$^3$ | Effluent PH | Elaps. Time Min Sec | Q cm$^3$/s | Q/HL cm$^2$/sec. | K' cm/sec. | K cm/sec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Statically Recompacted Density = 126.5 #/ft$^3$ | | | | | | | | | | $L/_A$ = 3.14 x 10$^{-2}$ | | | | |
| 11-9 | 1945 | 4827 | 4827 | 21.8 | 21.0 | ( 9.00" Hg) | | 122 | 311 | 70 | | 12-25 | .00940 | $3.02\times10^{-4}$ | $9.50\times10^{-6}$ | $9.27\times10^{-6}$ |
| | 1957 | 4827 | 4827 | 21.8 | 21.0 | ( 9.00" Hg) | | 122 | 311 | 100 | | 17-45 | .00938 | $3.02\times10^{-4}$ | $9.50\times10^{-6}$ | $9.27\times10^{-6}$ |
| | 2037 | 4793 | 4790 | 21.8 | 21.0 | (19.20" Hg) | | 261 | 664 | 100 | | 8-33 | 0.195 | $2.94\times10^{-4}$ | $9.23\times10^{-6}$ | $9.02\times10^{-6}$ |
| | | Statically Recompacted Density = 130.2 #/ft$^3$ | | | | | | | | | | $L/_A$ = $3.04\times10^{-2}$ | | | | |
| 11-9 | 2212 | 8112 | 8120 | 22.0 | 21.4 | (20.40" Hg) | | 278 | 705 | 25 | | 8-37 | .0483 | $6.86\times10^{-5}$ | $2.08\times10^{-6}$ | $2.01\times10^{-6}$ |
| | 2228 | 8128 | 8134 | 22.0 | 21.4 | (20.40" Hg) | | 278 | 705 | 50 | | 17-45 | .0470 | $6.67\times10^{-5}$ | $2.03\times10^{-6}$ | $1.96\times10^{-6}$ |
| | 2331 | 8138 | 8139 | 22.0 | 21.4 | (20.40" Hg) | | 278 | 705 | 15 | | 6-19 | .0396 | $5.96\times10^{-5}$ | $1.81\times10^{-6}$ | $1.75\times10^{-6}$ |
| | 2340 | (Outlet valve closed) (Air pressure turned off) | | | | | | | | | | | | | | |
| 12-9 | 1222 | 9146*9143 | | 23.0 | 22.0 | (19.05" Hg) | | 259 | 658 | 50 | | 15-32 | .0537 | $8.15\times10^{-5}$ | $2.48\times10^{-6}$ | $2.36\times10^{-6}$ |

* Note sample rebound.

PERMEABILITY DATA SHEET

Sample No. 1 — Initial Dry Density 141.0 #/ft$^3$

Material: Winger Pit (-3") — $L/A$ = 3.02 x $10^{-2}$ cm$^{-1}$

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp. °C In | Temp. °C Out | Total Head In | Total Head Out | H1 in. | H1 cm. | Effluent Vol. cm$^3$ | Effluent PH | Elaps. Time Min Sec | Q cm$^3$/s | Q/HL cm$^2$/sec. | K' cm/sec. | K cm/sec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12-8 | 1042 | 7388 | | | 20.8 | +21.4 | -28.1 | 49.5 | 126.0 | 250 | 8.20 | 15-00 | 0.278 | $2.20\times10^{-3}$ | $6.66\times10^{-5}$ | $6.54\times10^{-5}$ |
| | 1115 | 7384 | | | 20.9 | +21.2 | -28.1 | 49.3 | 125.5 | 250 | | 14-32 | 0.287 | $2.28\times10^{-3}$ | $6.90\times10^{-5}$ | $6.76\times10^{-5}$ |
| | 1140 | 7380 | | | 21.1 | +21.1 | -28.1 | 49.2 | 125.3 | 250 | 8.36 | 14-42 | 0.284 | $2.25\times10^{-3}$ | $6.80\times10^{-5}$ | $6.62\times10^{-5}$ |
| | 1400 | 7379 | | | 22.0 | +19.9 | -28.1 | 48.0 | 122 | 250 | 8.71 | 16-27 | 0.254 | $2.08\times10^{-3}$ | $6.27\times10^{-5}$ | $5.96\times10^{-5}$ |
| | 1417 | Outlet closed - lines changed for pressure operation.* | | | | | | | | | | | | | | |
| 12-8 | 1435 | 7234 | | | 22.0 | (10.90" Hg) | | 148 | 376 | 250 | | 2-31 | 1.66 | 0.453 | $1.37\times10^{-4}$ | $1.31\times10^{-4}$ |
| | 1443 | 7214 | | | 22.0 | (11.15" Hg) | | | 398 | 250 | | 2-43 | 1.53 | 0.385 | $1.16\times10^{-4}$ | $1.11\times10^{-4}$ |
| | 1528 | N.R. | | | 21.8 | (10.98" Hg) | | | 379 | 250 | 8.83 | 3-24 | 1.22 | 0.315 | $9.82\times10^{-5}$ | $9.40\times10^{-5}$ |
| | 1541 | 7135 | | | 21.8 | (18.90" Hg) | | | 652 | 250 | | 2-14 | 1.84 | 0.282 | $8.55\times10^{-5}$ | $8.19\times10^{-5}$ |
| | 1600 | 7090 | | | 21.8 | (18.90" Hg) | | | 652 | 250 | | 2-50 | 1.47 | 0.226 | $6.80\times10^{-5}$ | $6.52\times10^{-5}$ |
| | 1604 | Outlet valve closed - Lines changed to gravity operation | | | | | | | | | | | | | | |
| 12-8 | 1624 | 7410 | | | 21.8 | +15.0 | -28.1 | 43.1 | 109.5 | 250 | | 22-16 | 0.187 | $1.71\times10^{-3}$ | $5.16\times10^{-5}$ | $4.94\times10^{-5}$ |
| | 1649 | 7350 | | | | | | | | | | | | | | |
| | 1910 | 7240 | | | 21.6 | +14.0 | -28.2 | 42.2 | 107.2 | 250 | 8.90 | 27-42 | 0.150 | $1.40\times10^{-3}$ | $4.24\times10^{-5}$ | $4.08\times10^{-5}$ |
| | 2120 | 7232 | | | | | | | | | | | | | | |
| 13-8 | 1152 | 7247 | | | 20.5 | +10.5 | -28.2 | 38.7 | 97.4 | 45 | 8.93 | 10-22 | .0722 | $7.42\times10^{-4}$ | $2.24\times10^{-6}$ | $2.22\times10^{-5}$ |
| | 1205 | Outlet valve closed. | | | | | | | | | | | | | | |

* Note - Sample accidentally disturbed during this operation.

PERMEABILITY DATA SHEET

Sample No. 2

Initial Dry Density 134.0 #/ft$^3$

Material: Winger Pit (-3") + 1% Lime + 2% Fly Ash

| Date | Time | Dial Rd. Start mm | Dial Rd. End mm | Temp. °C In | Temp. °C Out | Total Head In | Total Head Out | Hl in. | Hl cm. | Effluent Vol. cm$^3$ | Effluent PH | Elaps. Time Min.Sec. | Q cm$^3$/s | Q/HL cm$^2$/sec | K' cm/sec | K cm/sec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16-8 | 1152 | 0970 | - - | 21.7 | | - 5.3 | -26.5 | 21.2 | 53.8 | 250 | | 5-20 | 0.781 | $1.45\times10^{-2}$ | $4.59\times10^{-4}$ | $4.41\times10^{-4}$ |
| 16-8 | 1230 | 0973 | - - | 21.7 | | - 6.0 | -26.4 | 20.4 | 51.8 | 250 | | 5-02 | 0.827 | $1.60\times10^{-2}$ | $5.05\times10^{-4}$ | $4.85\times10^{-4}$ |
| | 1238 | Permeameter shut down. | | | | | | | | | | | | | | |
| 16-8 | 1455 | 0972 | - - | 22.2 | | +13.8 | -23.5 | 37.3 | 94.7 | 1000 | | 10-16 | 1.62 | $1.71\times10^{-2}$ | $5.40\times10^{-4}$ | $5.12\times10^{-4}$ |
| 16-8 | 1520 | 0972 | - - | 22.5 | | +12.1 | -23.6 | 35.7 | 90.6 | 1000 | | 10-39 | 1.56 | $1.73\times10^{-2}$ | $5.46\times10^{-4}$ | $5.14\times10^{-4}$ |
| 16-8 | 1740 | 0977 | - - | 23.0 | | + 5.4 | -23.9 | 29.3 | 74.4 | 1000 | | 12.29 | 1.33 | $1.79\times10^{-2}$ | $5.66\times10^{-4}$ | $5.26\times10^{-4}$ |
| 16-8 | 1947 | 0982 | - - | 23.1 | | + 0.2 | -24.2 | 24.4 | 62.0 | 1000 | | 15-07 | 1.10 | $1.78\times10^{-2}$ | $5.63\times10^{-4}$ | $5.23\times10^{-4}$ |
| | | Dynamically Recompacted Density = 135.0 #/ft$^3$; L/A = 3.14 | | | | | | | | | | | | | | |
| 17-8 | 1350 | 7014 | 22.8 | 21.8 | | (16.55"Hg) | | 225 | 572 | 250 | | 2.02 | 1.79 | $3.13\times10^{-3}$ | $9.84\times10^{-5}$ | $9.41\times10^{-5}$ |
| 17-8 | 1402 | 7010 | 22.8 | 21.8 | | (16.47"Hg) | | 224 | 568 | 1000 | | 9-01 | 1.85 | $3.25\times10^{-3}$ | $1.02\times10^{-6}$ | $9.76\times10^{-5}$ |

Laboratory Compaction Control Data Page 1

Material: - Crawford Pit (-3")

Sample No. - 11

Additive Content: 0.50% N.P.C.

1. Air Dry Wt. Spec + Additive + Tare = 80.65#

Tare = 4.81#

Wt. Spec 75.84

Computed Hydroscopic M.C. = 1.17%

∴ Dry Weight Material = $\frac{75.84}{1.012}$ = 75.0#

Mixing Water Added 2.2 liters.

2. Initial Compaction:-

(a) Control Computations:-

(i) Desired Density = 120#/ft$^3$

(ii) X Sec. Area of Mold - 113.1; Depth = 24.37"

(iii) ∴ Req. Length Spec = $\frac{75.00}{120.0} \times \frac{1728}{113.1}$ = 9.54"

(iv) Depth of Mold 24.37

Desired Length Spec -9.54

Req. Depth to Spec 14.83

Thickness of Piston -0.76"

Req. Depth to Piston 14.07"

(b) Observed Data

(i) Length of Perm. Barrel = 12.04"

Average Depth of Spec = 2.53

Length Spec = 9.51"

(ii) Vol. Spec = $\frac{9.51 \times 113.1}{1728}$ = 0.622 ft.$^3$

(iii) Initial Dry Density = $\frac{75.0}{0.622}$ = 120.5 #/ft$^3$

(iv) Initial Void Ratio = $\frac{Gs\ Ow}{Ws} - 1 = \frac{62.4 \times 2.69}{120.5} - 1 = 0.39$

---

3. Second Compaction

(a) Control Computations

(i) Desired Density = 127. #/ft$^3$

(ii) Req. Length = $\frac{75.0}{127} \times \frac{1728}{113.1}$ = 9.02"

(iii) Depth of Barrel 12.04

Desired Length Spec 9.02

Req. Depth of Spec 3.02"

Thickness of Piston 1.17"

Req. Depth to Piston 1.85"

(b) Observed Data

(i) Length of Perm. Barrel 12.04

Ave. Depth of Spec 2.95

Length of Spec 9.09

(ii) Vol. Spec = $\frac{9.09 \times 113.1}{1728} = 0.595 \text{ ft}^3$

(iii) Dry Density = $\frac{75.0}{0.595} = 126.1 \text{ \#/ft}^3$

(iv) Void Ratio = $\frac{62.4 \times 2.69}{126.1} - 1 = 0.33$

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4. Third Compaction:

(a) Control Computations:

(i) Desired Density 131#

(ii) Req. Length = $\frac{75.0}{131} \times \frac{1728}{113.1} = 8.74"$

| | |
|---|---|
| (iii) Depth of Barrel | 12.04 |
| Desired Length Spec | -8.74 |
| Req. Depth to Spec | 3.30 |
| Thickness of Piston | -1.17" |
| Req. Depth to Piston | 2.13 |

(b) Observed Data

| | |
|---|---|
| (i) Length of Barrel | 12.04 |
| Depth of Spec | -3.24 |
| Length Spec | 8.80 |

(ii) Vol. Spec $\frac{8.80 \times 113.1}{1728} = 0.576$

(iii) Dry Density = $\frac{75.0}{0.576} = 130.1 \text{ \#/ft}^3$

(iv) Void Ratio $\frac{62.4 \times 2.69}{130.1} = 0.29$

5. Moisture Content of Discorded Spec

| | |
|---|---|
| Wt. Soil Wet + Tare | 37.87# |
| Wt. Soil Dry + Tare | 34.75# |
| Wt. of Water | 3.12# |
| Tare | 4.60# |
| Wt. Dry Soil | 30.15# |
| M. C % | 10.35% |

6. Final Degree of Saturation

$$S = \frac{W\ Gs}{c} = \frac{10.35 \times 2.69}{0.29} = 96\%$$

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